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Soil Survey of Iowa, Report No. 60—Carroll County Soils

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SOIL SURVEY OF IOWA

Report No. 60—CARROLL COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of A. M. O'Neal, H. R. Meldrum and L. W. Forman

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CARROLL COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of A. M. O'Neal, H. R. Meldrum and L. W. Forman.

Carroll County is located in west central Iowa in the third tier of counties east of the Missouri River and in the center tier of counties north and south. It is partly in the Wisconsin drift soil area and partly in the Missouri loess soil area, and hence the soils of the county are partly of loessial and partly of drift origin.

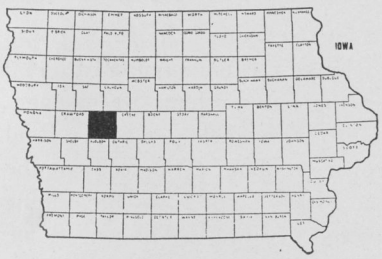

Fig. 1. Map showing the location of Carroll County.

The total area of Carroll County is 573 square miles or 366,720 acres. Of this area, 355,238 acres or 96.9 percent are in farm land. The total number of farms is 2,178 and the average size of the farms is 163 acres. Owners operate 42.8 percent of the total farm land and renters operate the remaining 57.2 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1928 show the utilization of the farm land in the county:

Acreage in general farm crops	255,731
Acreage in farm buildings, feed lots and public highways	19,795
Acreage in pasture	78,827
Acreage in waste land not utilized for any purpose	1,918
Acreage in farm woodlots used for timber only	608
Acreage in crop land lying idle	363
Acreage in crops not otherwise listed	133

THE TYPE OF AGRICULTURE IN CARROLL COUNTY

The type of agriculture most commonly followed in Carroll County at the present time consists of a system of general farming including the raising and feeding of hogs, beef cattle and sheep, dairying, and the production of such general crops as corn, oats and hay. The income on the farms is derived mainly from the sale of livestock and surplus grain crops. Many farms are operated on a strict livestock basis, and all the crops produced are utilized for feeding purposes. Dairy farming is practiced to a limited extent, but there are a few farms which are devoted exclusively to dairying. In general, farm income is chiefly derived from the sale of hogs. Income from beef cattle is second in importance, and that from the sale of sheep and dairy products is third. Finally, the income from the sale of surplus farm crops may be listed. On individual farms considerable income is derived from the sale of special crops, poultry, poultry products and from other sources.

There is a considerable acreage in waste land in the county, much of which might be reclaimed and made productive thru proper methods of soil management. General recommendations for the treatment of such land cannot be given as the causes of unproductiveness are variable, and different methods must be followed in different cases. In a later section of this report suggestions will be offered for the

* See Soil Survey of Carroll County, Iowa, by A. M. O'Neal, of the Iowa Agricultural Experiment Station, and R. E. Devereaux of the United States Department of Agriculture. Field Operations of the Bureau of Soils, 1926.

handling of various soil types on which crop yields at present are not entirely satisfactory. In special cases where the conditions are more or less abnormal, advice regarding soil treatments will be furnished by the Soils Section of the Iowa Agricultural Experiment Station upon request.

THE CROPS GROWN IN CARROLL COUNTY

General farm crops grown in Carroll County in the order of their importance are corn, oats, hay, barley, wheat, potatoes, alfalfa and rye. The acreage, yield and value of these crops are given in table I.

Corn is the most important crop both in acreage and in value. In 1928 it was grown on 38.6 percent of the total farm land and average yields amounted to 44.0 bushels per acre. On the better areas and under the best systems of management, yields are very much higher, ranging from 60 to 90 bushels per acre. Reid Yellow Dent is the most popular variety and is grown on about 60 percent of the total acreage in corn. In the northeastern part of the county some Iowa Silvermine and Silver King are grown. A small acreage is devoted to Iowa Goldmine. Some of the corn is used for silage, and in many cases where it is to be utilized in this way, soybeans are planted with the corn. About 80 percent of the crop is used for feed, either being fed on the farms where it is produced or sold in the county. Most of the corn crop sold to outside markets comes from the eastern half of the county and is sold to cooperative elevators.

Oats rank second in acreage and value. In 1928, this crop was grown on 21.3

TABLE I. ACREAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN CARROLL COUNTY, IOWA*

Crop	Acreage	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	137,236	38.6	44.0	6,038,384	$ 0.67	$4,045,717
Oats	75,778	21.3	37.7	2,855,890	0.36	1,028,120
Winter wheat	968	0.3	19.5	18,833	1.00	18,833
Spring wheat	592	0.2	17.7	10,450	1.01	10,555
Barley	10,863	3.1	33.5	363,721	0.54	196,409
Rye	160	0.05	11.0	1,760	0.86	1,514
Clover hay†	1,281	0.4	1.85	2,370	13.00	30,810
Timothy hay	4,473	1.3	1.29	5,770	10.50	60,585
Clover and timothy hay (mixed)	13,008	3.7	1.48	19,252	13.00	250,276
Alfalfa	3,554	1.0	3.46	12,297	16.50	202,901
All other tame hay	779	0.2	1.79	1,394	13.00	18,122
Wild hay	3,290	0.9	1.34	4,409	10.00	44,090
Soybeans grown with other crops	577	0.2	-----	-----	-----	-----
Soybeans grown alone	37	0.01	-----	-----	-----	-----
Soybeans grown for seed	11	0.01	20.0	220	1.78	392
Potatoes	1,146	0.3	100.0	114,600	0.51	58,446
Popcorn	337	0.09	-----	-----	-----	-----
Timothy seed	68	0.02	4.0	272	2.15	585
Clover seed†	59	0.01	0.8	47	18.00	846
Sweet clover seed	50	0.01	2.0	100	5.00	500
Sweet clover‡	2,052	0.6	-----	-----	-----	-----

*Iowa Yearbook of Agriculture, 1928.
†Sweet clover not included.
‡All varieties for all purposes.

percent of the total farm land and average yields amounted to 37.7 bushels per acre. The varieties most commonly used are Iowa 103, Green Russian, Silvermine, Kherson and Iowa 105, named in the order of their importance. On the better soils and under favorable conditions, yields of oats frequently amount to 50 or 60 bushels per acre. The greater part of the crop is used on the farms as feed for work animals, cattle and hogs, and only about 15 or 20 percent is shipped to outside markets.

Hay and forage crops are third in importance. Clover and timothy mixed is the most extensively grown hay crop. It yielded 1.48 tons per acre on the average in 1928. Some timothy is grown alone as is some clover. The timothy yielded 1.29 tons and the clover 1.85 tons per acre in 1928. Small acreages of both crops are grown for seed. Alfalfa is grown on a limited acreage and yields in 1928 amounted to 3.46 tons per acre. Wild hay was grown on 0.9 percent of the total farm land during the same season and yielded 1.34 tons per acre. The value of all hay and forage crops is considerable. All the hay produced is used on the farms for feed and the supply is not adequate. Where cattle feeding is practiced extensively, a large tonnage of hay is shipped in each year.

Barley is grown to some extent. In 1928 it yielded 33.5 bushels per acre. The wheat acreage is rather small, winter wheat yielding 19.5 bushels per acre and the spring varieties 17.7 bushels per acre in 1928. Turkey and Iobred are the most popular varieties. Most of the wheat produced is sold at the flour mills in Carroll, Manning and Westside, Crawford County. A small tonnage is sold on outside markets. Some rye is grown for pasturage. Buckwheat serves as a catch crop and flax is sometimes grown on poorly drained land. Sorghum is produced to a small extent and is used for forage and syrup. Some millet and sudan grass are grown for forage and pasturage.

Soybeans are grown to some extent and the varieties most favored are Ito San and Manchu. Sweet clover is not extensively grown but is rapidly gaining in favor. Both the yellow and white varieties are being produced. This crop is sometimes used for seed but generally for pasture. Alfalfa is a particularly popular hay crop and the acreage is constantly increasing. The varieties most favored are Grimm and Dakota No. 12. Three cuttings are commonly obtained and the yields are high. When the soils are limed and the crop is inoculated, very satisfactory results are secured.

There are gardens on most farms and all varieties of vegetables are produced for home consumption. In the sandier sections in the northeastern part of the county, a few truck farmers grow watermelons, cantaloupes and vegetables on a commercial scale. There are a few orchards but they receive little attention and fruit production is of minor significance. Some grapes, raspberries and strawberries are produced on most farms.

THE LIVESTOCK INDUSTRY IN CARROLL COUNTY

The livestock industry includes the raising and feeding of hogs and cattle, dairying, the raising of sheep and to some extent the breeding of horses. The following figures taken from the Iowa Monthly Crop Report for July 1, 1928, which gives Jan. 1, 1928, estimates, show the extent of the livestock industry in the county.

These estimates are made by the United States Department of Agriculture, Bureau of Agricultural Economics, in cooperation with the Iowa State Department of Agriculture:

Horses	12,300
Mules	1,210
Cattle, all	41,200
Hogs	94,100
Sheep	5,100

The principal livestock industry is the raising and feeding of hogs. The Duroc Jersey, Poland China and Chester White are the most popular breeds but a few Hampshires and Tamworths are raised. About 60 head of hogs is the average number per farm. The hogs are sold either directly to buyers or shipped thru cooperative associations. Feeders are often brought in from Sioux City and Omaha. Most of the fattened hogs are shipped to Chicago and Omaha.

The raising and feeding of beef cattle is also important. A few herds are pure-bred but most of them consist of grade animals. Shorthorn and Hereford cattle predominate but there are some Aberdeen Angus. Feeders are bought on the Omaha and Sioux City markets and are shipped into the county late in the fall. They are fed intensively for a period ranging from 100 to 160 days and are sold chiefly on the Chicago market.

Dairying is carried on to some extent but usually as a side line. In the vicinity of Carroll and Manning, a few farmers devote their entire time to this industry. The Holstein is the most popular dairy breed altho there are a number of Guernsey herds. From 7 to 12 cows are commonly kept. The milk is separated on the farms and the cream is sold to creameries located at Carroll, Breda, Templeton, Manning, Halbur, and Roselle or to cream stations in the smaller towns. The butter produced in the local creameries is sold locally and on outside markets.

A few farmers keep sheep, mainly Shropshire and Oxford grades. Some of the small flocks are kept as side lines. A few farmers ship in feeders from the west which are fed intensively from 40 to 60 days until fit for market. The local flocks are sheared each year and the wool is marketed thru wool growers' associations. A few horses and mules are raised on the farms, chiefly to supply local needs.

Chickens, ducks, geese, turkeys and a few guinea fowls are raised. The production of chickens and eggs is becoming of more significance as farmers are realizing the value of poultry and poultry products. The chickens and eggs are sold either to the produce houses located in the principal towns or are exchanged for necessities at the stores.

THE FERTILITY CONDITION OF CARROLL COUNTY SOILS

The yields of general farm crops in Carroll County are generally satisfactory, but in many cases much larger crops might be secured thru proper methods of soil management. In some cases the natural drainage of the soil is not adequate, and when this is true the installation of tile is the first soil treatment needed to make the land properly productive. Crop yields will not prove satisfactory on land which is too wet, and even if the expense of tiling is considerable, its installation will prove very desirable economically because of the greater value of the crops secured. The Webster silty clay loam and the Webster loam on the drift uplands

are naturally poorly drained, and on these types drainage is very necessary in all cases where it has not already been taken care of thru the proper installation of tile. There are some areas in the other upland types where drainage would prove of value, especially in the Carrington loam and the Clarion loam areas. The Bremer and Fargo soils on the terraces and the Wabash and Lamoure types on the bottoms are all in need of drainage. In all these cases the installation of a satisfactory drainage system is essential before any other soil treatments are employed if beneficial effects are to be secured.

Many of the soils in Carroll County are acid in reaction and hence are in need of lime if the best crop yields are to be secured. In some cases the Clarion and Webster soils are well supplied with lime. The Pierce sandy loam is almost always high in lime. The other upland types, however, are usually deficient. The Fargo soils on the terraces contain lime, and the Lamoure types on the bottoms are well supplied with this constituent, but the other terrace and bottomland soils are acid in reaction. It is very desirable, therefore, that all the soils in the county except the Pierce, Fargo and Lamoure types be tested for lime needs and that proper application of lime be made if crop growth is to be satisfactory. Large increases in the yields of such crops as alfalfa and sweet clover may be obtained by applications of lime to acid soils. Beneficial effects are also evidenced in many cases on other farm crops. For building up and maintaining the fertility of the soils of this county, the application of lime as needed is certainly a fundamental treatment.

The supply of organic matter and nitrogen is quite adequate in many of the soil types, but in some cases the soils are low in these constituents. It is necessary, however, that fertilizing materials supplying nitrogen and organic matter be added to the land at regular intervals if the content of these constituents is to be kept up. The application of farm manure is of large value on practically all of the soils in the county. On the dark colored heavy types such as the Webster, Fargo, Bremer, Wabash and Lamoure soils, large applications of manure should not be made, especially preceding the growing of a small grain crop as they may cause the crop to lodge. Small applications will prove of value, however, even on these soils, to stimulate the production of available plant food. Additions of manure are particularly desirable where the land is newly drained. Large increases in crop yields follow the application of manure on the Carrington, Clarion, Marshall, O'Neill and Waukesha types. Crop residues should be utilized on the farm to aid in maintaining the supply of organic matter and nitrogen. The turning under of leguminous crops as green manures is very desirable where farm manure is not available in sufficient amounts to permit of a regular supply to all the land on the farm. Legumes when well inoculated take much of their nitrogen content from the atmosphere and hence when turned under will increase the nitrogen content of the soil, while at the same time they add valuable organic matter. On the Carrington, Clarion, O'Neill and Waukesha types, the practice of green manuring is of special value, but even on the other soils the practice may be desirable to keep up the fertility of the land.

The phosphorus content of the soils of Carroll County is not high and applications of phosphorus fertilizers will certainly be needed in the very near future.

In many cases the application of rock phosphate or superphosphate has already proved of large value. Farmers are urged to test both phosphate fertilizers on small areas in order to determine definitely the need of phosphorus on their land and also to show whether rock phosphate or superphosphate will prove most economical. Results with these two fertilizers have been variable, and a definite choice between the two materials cannot be made for all conditions.

Complete commercial fertilizers may be used profitably in some cases, but in general superphosphate or rock phosphate probably will prove more economical. The latter materials are much less expensive and hence may prove more desirable if they bring about almost as large increases. There is no objection to the use of a complete commercial fertilizer if profitable effects are secured, but no complete brand should be employed extensively until tests have been carried out in comparison with superphosphate on a small area to determine the relative value of the two materials. Commercial nitrogenous and potassium fertilizers are probably unnecessary on most of the soils. In small amounts as top dressings their use may be desirable in individual cases, but they should never be employed until tests on small areas have been carried out and their value proven for the particular conditions under consideration.

Erosion occurs to some extent in Carroll County but it is not nearly as significant as in many other counties. The Marshall silt loam, Carrington loam, Clarion loam and occasionally some of the other upland types are somewhat injured by this destructive action. Some gullies are formed and sheet washing occasionally occurs which brings about the removal of some of the fertile surface soil. Wherever these destructive effects of erosion are evident, some method should be employed to prevent or control the action.

THE GEOLOGY OF CARROLL COUNTY

The soils of Carroll County are derived mainly from glacial and loessial deposits, and it is unnecessary, therefore, to consider the geological history of the county in any detail. The bedrock is buried so deeply by the glacial deposits and later loessial covering that it has no effect upon the soils of the county.

During the glacial age at least two great ice sheets swept over the county, and each left behind a thick layer of glacial drift or debris. The earlier deposits have been very largely carried away by the later glaciers. The topographic features of the county established following the earlier glaciation were largely obliterated by the succeeding ice sheet.

The first glacier which invaded the county is known as the Kansan. The deposit of drift material left by this ice sheet consisted mainly of a mixture of blue clay containing numerous pebbles, boulders and rock fragments and frequently much sand and gravel. The depth of the deposit was undoubtedly extremely variable, ranging from a few feet in certain areas to many feet in other locations. When weathered the Kansan drift material changes to yellow or red. The soils of the county are only very slightly influenced by this early drift sheet. The effects are evidenced in the lower subsoil of some of the types of the Carrington and Clarion series, and the Pierce soils are possibly partly Kansan in origin. These latter types,

SOIL MAP OF CARROLL COUNTY IOWA

Thomas D. Rice, Inspector, District 3. Soils Surveyed by A. M. O'Neal, of the Iowa Agricultural Experiment Station in charge, and R. E. Devereux, of the U. S. Department of Agriculture.

U. S. DEPT. OF AGRICULTURE, BUREAU OF CHEMISTRY AND SOILS
Henry G. Knight, Chief. A. G. McCALL, in Charge Soil Investigations
Curtis F. Marbut, in charge Soil Survey

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss. Director W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in Charge

SCALE: 1 INCH TO 2½ MILES

LEGEND

Drift Soils

1 Carrington loam	107 Webster silty clay loam	138 Clarion loam
55 Webster loam	149 Clarion fine sandy loam	
234 Clarion fine sandy loam (Steep phase)	4 Carrington fine sandy loam	191 Pierce sandy loam

Loess Soils

9 Marshall silt loam

Terrace Soils

109 Fargo silty clay loam	108 O'Neill loam	152 Fargo silt loam
88 Bremer silt loam	110 O'Neill fine sandy loam	75 Waukesha silt loam
43 Bremer silty clay loam	146 O'Neill fine sand	

Swamp and Bottomland Soils

26-A Wabash silt loam (Colluvial phase)	111 Lamoure silty clay loam	48 Wabash silty clay loam
26 Wabash silt loam	49 Wabash loam	

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however, are mostly formed in the terminal moraine of the glacier.

The later ice sheet which invaded the county is known as the Wisconsin. It covered the entire area and deposited a thick layer of glacial drift. The deposit when unweathered is a bluish-drab to bluish-gray in color, changing to a yellow or buff when weathered. It consists of a mixture of clay, sand, gravel and boulders. During the years which have passed since this deposit was laid down, much weathering has occurred, organic matter has accumulated and some leaching has taken place. The upland soils of the county except the Marshall silt loam are derived from this Wisconsin drift material. In the northeastern half of the county and along the narrow, deeply cut valleys in the southwestern part, the soils of drift origin are found on the surface of the uplands. The upper part of the drift consists of a yellowish-brown, gritty or fine sandy clay loam or fine sandy clay; at the lower depths the material is either a yellowish-brown, gritty, fine sandy loam streaked with rusty brown and black iron stains or a pale yellow, light textured loam spotted with gray and black. Boulders and gravel may occur on the surface or thruout the three-foot section. In the level to depressed areas where there has been an especially large accumulation of organic matter, the soils are of the Webster series and are very black in color. On the undulating to gently rolling uplands where the lime has been leached below the three-foot depth, the soils are mapped in the Carrington series, and where lime occurs within three feet of the surface, the soils are correlated in the Clarion series. These types have accumulated some organic matter and are typically dark grayish-brown in color in the surface soil. Unleached calcareous drift with gravelly subsoils is mapped in the Pierce series.

Later in geological history, when climatic conditions were very different than at present, a layer of fine dustlike material known as loess, was deposited over the southwestern part of the county. Over the greater part of this area it ranges from 3 to 40 feet in thickness. There has been some incorporation of organic matter in the surface layers. Because of a complete removal of calcareous material presumably originally carried in the loess, the loessial soil now occurring in the county is acid in reaction. The Marshall silt loam is the only loess type in the county.

The soils of the second bottomland and first bottoms have been developed along the various drainageways of the county from reworked and redeposited drift or loess materials washed down by the streams. They are very similar in many characteristics to the upland types and are uniformly dark in color and occasionally high in lime content. This is the case with the Fargo silt loam, the Fargo silty clay loam on the terraces and the Lamoure silty clay loam on the bottoms. In the loessial section of the county, much of the bottomland soil material is of loessial origin, while in the drift section the soils on the terraces and bottoms are entirely made up of drift material. The Bremer soils are heavy and black in color, with impervious subsoils. The O'Neill soils have a sandy or gravelly subsoil. The Waukesha types are dark in color but do not have the heavy subsoils of the Bremer nor the sandy subsoils of the O'Neill. They are naturally better drained than the former and are not drouthy like the latter. On the bottomlands the Wabash soils are heavy in texture and are poorly drained.

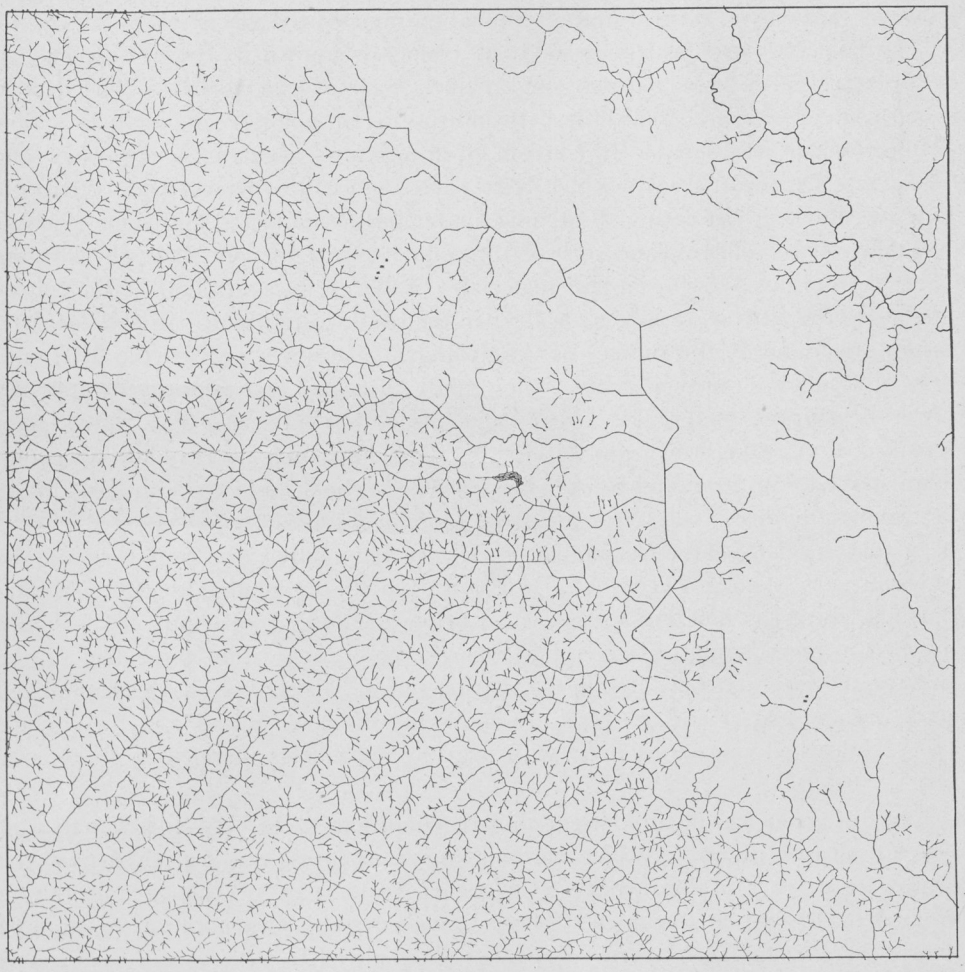


Fig. 2. Map showing the natural drainage system of Carroll County.

PHYSIOGRAPHY AND DRAINAGE

There are two distinct topographic features in Carroll County, corresponding with the loessial and glacial areas. The line separating the two soil areas runs thru Breda, Carroll and Coon Rapids. West of this line in the loessial section, the topography is undulating to strongly undulating or even rolling. The tops of the divides are about 50 feet higher than the average of the valley floors. The divides, however, are well rounded and the slopes to the streams are smooth. The general appearance of the topography in this section of the county is more level than is really the case. Actually the topography in general is strongly rolling.

East of the line separating the loess and drift areas, the topography is undulating or rolling, except in the extreme northeastern corner of the county where there are rough rugged strips occurring adjacent to the bottomlands of the Raccoon River. The general surface of the uplands thruout this drift section of the county varies from gently undulating to nearly level.

The drainage of the county is brought about by the Raccoon River in the

northeastern corner, the Middle Raccoon River with its tributaries, chief of which are Willow Creek and Spring Creek, in the central part, Rusty Ford Creek in the middle southwestern section and the Nishnabotna River in the southwestern corner. Thruout the loessial area, the natural drainage system is fairly well developed and the streams or intermittent drainageways extend into practically all parts of the upland. In the drift section, however, the drainage is frequently rather poorly developed and considerable areas of the level to depressed uplands are poorly drained. The extent of the natural drainage system of the county is indicated in the accompanying drainage map.

Bottomlands are developed along all of the rivers and creeks of the county. Many of these areas are quite large. The broadest lie along the Middle Raccoon River from a point south of Lidderdale to the vicinity of Carrollton. Except for a few comparatively small isolated areas along the Middle Raccoon River and some of the larger creeks, terraces are found only along the valleys of the Raccoon River in the northeastern corner of the county.

THE SOILS OF CARROLL COUNTY

The soils of Carroll County are grouped into four classes according to their origin and location. These classes are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from deposits left by receding glaciers and consist of mixtures of sand, gravel and clay which frequently contain pebbles and boulders. Loess soils are fine, dust-like deposits laid down over the surface of the land by the wind, presumably at a time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a depression of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas and along streams. Many of them are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Carroll County are shown in table II.

Slightly less than one-half the total area of the county is covered by the drift soils, 43.4 percent. They are found on the uplands thruout the eastern half of the county. The loess soils which cover 38.6 percent of the county are somewhat smaller in area and are developed in the western half. Terrace soils are very limited in extent, covering only 4.6 percent of the total area. Swamp and bottomland soils are rather extensively developed along the various streams thruout the county and cover 13.4 percent of the total area.

There are 20 individual soil types in the county. These, together with the steep

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN CARROLL COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	159,680	43.4
Loess soils	141,632	38.6
Terrace soils	16,512	4.6
Swamp and bottomland soils	48,896	13.4
Total	366,720	----

phase of the Clarion fine sandy loam and the colluvial phase of the Wabash silt loam, make a total of 22 soil areas. There are eight areas of drift soil, one loess soil, eight terrace types and five areas classified as bottomland soils. The areas covered by the various soil types in the county are shown in table III.

The Carrington loam is the largest drift soil and the second largest soil type in the county. It covers 19.5 percent of the total area. The Webster silty clay loam is the second largest drift soil and the third largest type in the county. It covers 9.6 percent of the total area. The Clarion loam is the third largest type, covering 9.4 percent of the area. The Webster loam is much smaller in extent, covering 2 percent of the county. The Clarion fine sandy loam, together with the steep phase, covers 1.7 percent of the county. The two remaining drift soils, the Carrington fine sandy loam and the Pierce sandy loam, cover less than 1 percent of the county.

The Marshall silt loam is the only loess type and is the most extensively developed soil in the county. It covers 38.6 percent of the total area. The terrace soils are all limited in area. The largest, the Fargo silty clay loam, covers only 1.2 percent of the county. The remaining types mapped in the O'Neill, Bremer and Waukesha series, all cover less than 1 percent of the total area. The Wabash silt loam together with the colluvial phase which is much smaller in area is the largest bottomland type and covers 9.4 percent of the county. The Lamoure silty clay loam is the second largest bottomland soil, covering 2.4 percent of the total

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN CARROLL COUNTY

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	71,616	19.5
107	Webster silty clay loam	35,264	9.6
138	Clarion loam	34,496	9.4
55	Webster loam	7,488	2.0
149	Clarion fine sandy loam	3,712	1.7
234	Clarion fine sandy loam (steep phase)	2,432	
4	Carrington fine sandy loam	1,984	0.5
191	Pierce sandy loam	2,688	0.7
	LOESS SOILS		
9	Marshall silt loam	141,632	38.6
	TERRACE SOILS		
109	Fargo silty clay loam	4,288	1.2
108	O'Neill loam	3,136	0.9
152	Fargo silt loam	2,752	0.8
88	Bremer silt loam	2,240	0.6
110	O'Neill fine sandy loam	1,920	0.5
75	Waukesha silt loam	1,088	0.3
43	Bremer silty clay loam	896	0.2
146	O'Neill fine sand	192	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	25,600	9.4
26a	Wabash silt loam (colluvial phase)	8,960	
111	Lamoure silty clay loam	8,640	2.4
48	Wabash silty clay loam	3,520	1.0
49	Wabash loam	2,176	0.6
	Total	366,720	----

area. The Wabash silty clay loam covers 1 percent of the area while the Wabash loam, the smallest of the bottomland types, covers only 0.6 percent of the county.

There are some variations in the topography of the upland soils, especially in the drift sections of the county. The Carrington and Clarion soils are found on the more strongly undulating to rolling areas, while the Webster types occur on the more nearly level to flat areas. The Pierce sandy loam is found on knobs or ridges thruout the more strongly rolling areas. On the loessial uplands the Marshall silt loam, the only loess type mapped, is gently undulating to rather rolling. The topographic features are not very well developed on the terraces, but in general the O'Neill and Waukesha soils are found on the higher areas while the Fargo and Bremer types are found on the flat to depressed sections, many of which are only slightly above the level of the bottomland. The bottomland soils are all level to flat in topography.

The Fertility in Carroll County Soils

Samples were taken for analysis from each of the soil areas in the county, except the steep phase of the Clarion fine sandy loam. This was not sampled because of its small extent and its unimportance agriculturally. The more extensive soil types were sampled in triplicate while only one sample was taken from each of the minor types. The samplings were all made with care in order that the samples be representative of the individual soil types and that all variations due to previous treatment of the soil might be eliminated. The samples were taken at three depths, 0 to 6⅔ inches, 6⅔ to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil respectively.

The samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official methods were followed in the determination of the phosphorus, nitrogen and carbon, and the Truog qualitative test was used in the determination of the limestone requirements. The figures given in the tables are the averages of duplicate determinations on all samples of each type and they represent, therefore, the averages of two or six determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2 million pounds of surface soil per acre.

The phosphorus supply of the various soil types is somewhat variable, ranging from 929 pounds per acre in the Carrington fine sandy loam up to 2,694 pounds in the Fargo silty clay loam. There are no definite relationships apparent between the phosphorus content of the soils and the different soil groups. On the average the bottomland types are a little better supplied than the upland soils, which is natural since there has been less plant growth on the bottomlands and hence a smaller removal of phosphorus. The variations among the individual soil types are much more definite than between the various soil groups.

There is some evidence of a relationship between the phosphorus supply of the soils and the characteristics which serve as a basis to distinguish the various soil series. Differences in topography, in color, and in subsoil characteristics correspond to some extent with differences in phosphorus content. Generally those

TABLE IV. PLANT FOOD IN CARROLL COUNTY, IOWA, SOILS

Pounds per acre of 2 million pounds of surface soil (0-6⅔")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,329	3,920	38,532	-------	3,000
107	Webster silty clay loam	1,373	6,440	69,238	586	None
138	Clarion loam	1,400	3,680	29,396	-------	3,000
55	Webster loam	1,414	5,500	50,558	-------	3,000
149	Clarion fine sandy loam	1,266	3,580	34,085	1,147	None
4	Carrington fine sandy loam	929	2,700	29,751	-------	4,000
191	Pierce sandy loam	1,239	2,420	25,388	-------	4,000
	LOESS SOILS					
9	Marshall silt loam	1,468	5,030	38,805	-------	6,000
	TERRACE SOILS					
109	Fargo silty clay loam	2,694	10,380	76,605	4,714	None
108	O'Neill loam	1,414	3,520	37,209	-------	4,500
152	Fargo silt loam	2,006	8,740	50,366	34,798	None
88	Bremer silt loam	1,535	3,860	41,995	-------	2,000
110	O'Neill fine sandy loam	1,711	3,880	39,759	-------	3,000
75	Waukesha silt loam	1,684	3,740	39,405	-------	7,000
43	Bremer silty clay loam	2,154	6,840	76,874	-------	3,000
146	O'Neill fine sand	1,091	1,220	14,453	-------	3,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,723	3,530	37,387	-------	2,500
26a	Wabash silt loam (colluvial phase)	1,320	3,780	39,105	-------	7,000
111	Lamoure silty clay loam	1,778	5,880	43,530	7,083	None
48	Wabash silty clay loam	2,086	7,147	60,266	-------	3,000
49	Wabash loam	1,711	5,340	44,154	-------	None

types which are more level to flat in topography are higher in plant food. Those which are darker in color are richer in the various constituents, and types with heavy subsoils are better supplied with plant food than are types with gravelly subsoils. It appears that on the drift uplands the Webster soils are somewhat better supplied with phosphorus than the Carrington and Clarion types and the latter are somewhat richer in this element than the Pierce soils. On the terraces the Fargo and Bremer types are richer than the Waukesha and O'Neill, and the Waukesha soils are better supplied than the O'Neill types. The Webster soils are level to flat in topography and darker in color than the Carrington and Clarion soils and have heavier subsoils. The Carrington and Clarion types are richer than the Pierce soils, largely because of their heavier subsoil conditions. On the terraces the Fargo and Bremer soils are level to flat in topography, darker in color and have heavier subsoils. The O'Neill soils have sandy, gravelly subsoils and hence are lower in plant food than the other terrace types. On the bottomlands, the Wabash and Lamoure soils are very similar in characteristics and have about the same content of phosphorus.

The effect of soil texture is evident in some of the analyses. On the drift uplands, the Carrington loam is much richer in phosphorus than the Carrington fine sandy loam, and the Clarion loam is richer than the Clarion fine sandy loam, while the Webster silty clay loam and the Webster loam are very similar in phos-

phorus content with the loam showing a slightly larger amount. Ordinarily the silty clay loam would be somewhat richer. On the terraces the Fargo silty clay loam is much higher in phosphorus content than the Fargo silt loam, the Bremer silty clay loam is higher than the Bremer silt loam, and the O'Neill loam is higher than the O'Neill fine sand, but the O'Neill fine sandy loam is somewhat better supplied than the loam. This is contrary to the usual results. On the bottomlands the Wabash silty clay loam is higher than the silt loam which in turn is better supplied than the loam. It seems evident, therefore, that fine textured types may generally be expected to be better supplied with phosphorus than coarse textured soils. Silty clay loams are usually richer than silt loams, silt loams are better supplied than loams and these in turn are richer in phosphorus than are sandy loams or sands.

The analyses of the soils of the county as a whole indicate quite definitely that the phosphorus supply is not sufficient to meet the needs of crops for an indefinite period. Phosphorus fertilizers will certainly be needed on all of the soils in the very near future. It seems probable, however, from the evidence which has been secured in greenhouse experiments, in field tests and from the results secured by a number of farmers, that phosphorus fertilizers might be used in many cases at the present time with profit.

The nitrogen content of the soils of the county is extremely variable. It ranged from 1,220 pounds in the O'Neill fine sand up to 10,380 pounds in the Fargo silty clay loam. The terrace and bottomland soils seem to be a little better supplied with nitrogen than the upland types, but the differences are not very large in many cases and the relationships to the various soil groups are not very definitely shown. Ordinarily there are much wider differences in nitrogen content within the various groups than between groups, and naturally the terrace and bottomland soils might be expected to be a little better supplied with the element owing to the lower plant growth and smaller removal of the various plant food constituents from the soil.

There is some evidence of a relationship between the various soil series and the nitrogen supply. Thus on the drift uplands the Webster soils, which are more level to flat in topography, darker in color, and heavier in the subsoil than the other types, are the richest in nitrogen. The Carrington and Clarion soils, which are dark in color and have rather heavy subsoils, are better supplied with nitrogen than the lighter colored Pierce types which have gravelly subsoils. On the terraces the Fargo and Bremer soils, which are found on the level to depressed areas, are very dark in color, have heavy subsoils and are richer in nitrogen than the Waukesha and O'Neill types. The Waukesha soils which are darker in color and heavier in subsoil are better supplied with nitrogen than the O'Neill types which have sandy or gravelly subsoils. On the bottomlands the Wabash and Lamoure soils are very similar in nitrogen content, topographic conditions, color and subsoil characteristics. Apparently those soil characteristics which serve to distinguish the various soil series are reflected in the nitrogen content of the various types.

Textural differences in the soils are shown in a number of cases to have a very definite relationship to the nitrogen content. Thus, among the drift soils, the Webster silty clay loam is richer than the Carrington fine sandy loam, and the

Clarion loam is better supplied with nitrogen than the Clarion fine sandy loam. On the terraces the Fargo silty clay loam is richer in nitrogen than the Fargo silt loam. The Bremer silty clay loam is much better supplied than the Bremer silt loam. The O'Neill loam and the O'Neill fine sandy loam are very much richer in nitrogen than the O'Neill fine sand. The fine sandy loam is a little higher than the loam, which is contrary to the usual results. On the bottomlands, the Wabash silty clay loam is richer than the Wabash silt loam or the Wabash loam. The Wabash loam is a little higher than the silt loam, which is not in accordance with the usual results. In general, however, it appears that fine textured soils are better supplied with nitrogen than are coarse textured types. Silty clay loams are richer in this constituent than are silt loams, silt loams are better supplied than loams and loams in turn are richer in nitrogen than are sandy loams or sands.

While in general the supply of nitrogen in the soils of the county is not strikingly deficient, it is evident that this element must be considered when systems of permanent fertility are being planned.

The relationship between the content of nitrogen and organic carbon in soils usually indicates quite definitely the condition of the organic matter or the rate at which it is being decomposed, which, in turn, indicates the extent to which available constituents are being produced in the soil. If the relationship is not at the best, there is an especial need for the application of farm manure to stimulate decomposition processes and the production of available plant food. On a number of the soil types in this county, the relationship is not at the best, and the use of farm manure would be particularly desirable. Thus on the Carrington loam, the Clarion loam, the Webster loam, the Clarion fine sandy loam, the Carrington fine sandy loam, and the Pierce sandy loam, on the drift uplands, on the Marshall silt loam on the loess uplands and on several of the terrace and bottomland soils, the use of farm manure has been found by many tests to bring about very desirable effects.

The organic carbon content of the soils in this county varies considerably as is evident from the results in the table. The amount ranges from 14,453 pounds per acre in the O'Neill fine sand up to 76,605 pounds per acre in the Fargo silty clay loam. These are the same types which showed the lowest and highest content of nitrogen respectively. Usually there is a definite relationship between the nitrogen and carbon in soils, those which are high in organic carbon being well supplied with nitrogen. The color of the soil indicates the content of organic carbon and, therefore, to a certain extent also the content of nitrogen. Soils which are dark in color may be considered to be well supplied with organic matter and are usually rich in nitrogen.

The relationships among the various soils on the basis of their total organic carbon content are very much the same as those noted in the case of nitrogen. There is little evidence of any relation between the organic matter supply and the different soil groups altho the bottomland types are a little better supplied on the average than the upland soils. The relationships among the various soil series are similar to those noted in the case of nitrogen, and the same may be said of the relationships among the soil types.

The effects of the topographic position, the color of the soil, the subsoil charac-

teristics and the texture of the soil are evidenced in some of the results of the analyses. Thus, on the level to depressed uplands, the Webster soils are richer in organic matter than the Carrington, Clarion and Pierce types, and the Clarion and Carrington soils which have heavier subsoils are richer than the Pierce sandy loam. On the terraces the Fargo and Bremer types, which are depressed in topography, dark in color and have heavy subsoils, are richer in organic matter than the O'Neill and Waukesha types. The O'Neill types which have sandy subsoils are poorer in organic matter than the Waukesha types. The effects of texture are evidenced in a number of instances. The Webster silty clay loam is richer in organic matter than the Webster loam, and the Carrington loam is richer than the Carrington fine sandy loam. The Clarion loam is about the same in organic matter content as the Clarion fine sandy loam. Ordinarily the loam would be a little richer in this constituent. The Fargo silty clay loam on the terraces is richer than the Fargo silt loam. The Bremer silty clay loam is much better supplied than the Bremer silt loam. The O'Neill loam and the O'Neill fine sandy loam are richer than the O'Neill sand. The loam is a little lower than the fine sandy loam which is contrary to the usual results. On the bottomlands the Wabash silty clay loam is richer than the Wabash silt loam and the Wabash loam. The loam is a little higher than the silt loam which again is contrary to the usual results. In general, however, it seems that the fine textured soils are richer in organic matter than the coarse textured types just as was noted in the case of nitrogen.

While many of the soil types in the county are black in color and apparently well supplied with organic matter and nitrogen, the need of fertilizing materials supplying organic matter at regular intervals is very evident. If the soils are to be kept satisfactorily productive, materials supplying organic matter must be added regularly.

The upland soils in the county, except the Webster silty clay loam and the Clarion fine sandy loam, are acid in reaction and show no content of inorganic carbon. In most cases the types mentioned are acid in reaction at the surface, altho they contain lime in the lower soil layers, but in some instances, as in the case of the samples on which analyses were made here, the lime extends up into the surface soil. The terrace soils, except the Fargo types, are all acid in reaction as are all the Wabash soils on the bottoms. It is important, therefore, that all of the soils in the county, except the Fargo and Lamoure types, be tested for lime needs and that lime be applied as necessary if the best yields of general farm crops and especially of legumes are to be secured. Even the Webster soils on the upland should be tested for lime requirements as in some cases these types are acid in reaction at the surface.

THE SUBSURFACE SOILS AND SUBSOILS

Tables V and VI give the results of the analyses of the subsurface soils and subsoils. They are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre.

Unless there is a very large amount of some constituent in the lower soil layers or a striking deficiency in a constituent, there is little effect on the fertility of the soil indicated by the analyses of the lower soil layers. In general the results secured on the surface soil samples may be considered to show fairly accurately the

TABLE V. PLANT FOOD IN CARROLL COUNTY, IOWA, SOILS

Pounds per acre of 4 million pounds of subsurface soil (6⅔"-20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,269	5,235	54,417		5,000
107	Webster silty clay loam	2,586	7,720	76,036	1,247	None
138	Clarion loam	1,696	3,760	40,577		3,000
55	Webster loam	2,208	7,800	93,754		2,000
149	Clarion fine sandy loam	2,586	4,800	48,306	2,906	None
4	Carrington fine sandy loam	2,182	4,240	47,340		4,000
191	Pierce sandy loam	2,020	1,120	12,235	5,545	None
	LOESS SOILS					
9	Marshall silt loam	2,666	5,860	57,599		6,000
	TERRACE SOILS					
109	Fargo silty clay loam	3,716	8,040	104,937	1,470	None
108	O'Neill loam	2,384	4,060	46,986		4,000
152	Fargo silt loam	2,962	9,960	68,073	56,059	None
88	Bremer silt loam	2,558	5,160	60,812		3,000
110	O'Neill fine sandy loam	2,586	3,600	43,359		2,000
75	Waukesha silt loam	2,828	6,200	67,302		6,000
43	Bremer silty clay loam	1,938	7,920	118,839		2,000
146	O'Neill fine sand	1,992	2,440	32,942		3,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,151	7,120	79,574		2,500
26a	Wabash silt loam (colluvial phase)	3,340	7,840	81,973		7,000
111	Lamoure silty clay loam	2,908	5,080	54,051	23,014	None
48	Wabash silty clay loam	2,882	7,040	85,528		None
49	Wabash loam	3,178	7,547	79,180		None

plant food content and the crop-producing power of the soils. The lower soil layers in Carroll County are not particularly high in any constituents nor are they strikingly deficient. It is not necessary, therefore, to discuss these analyses in detail.

The conclusions reached in the discussion of the analyses of the surface soil are very largely confirmed. It appears that phosphorus fertilizers will be needed on the soils in the near future, and their use might be very desirable at the present time in many cases. It is important that the supply of organic matter and nitrogen be kept up in all the soils of the county. In some cases additions of fertilizing materials supplying organic matter and nitrogen are now very necessary. The proper use of farm manure, crop residues and leguminous green manures is very desirable on the soils of this county. The soils which are acid at the surface should be tested for lime needs, and lime should be applied as necessary, especially for the best growth of legumes. Even on the Webster soils on the drift uplands, which are usually high in lime in the lower soil layers, the surface soils frequently may be acid, and for new seedings of legumes additions of lime may be necessary. On all the other upland types the soils are acid and in need of lime. On the terraces and bottomlands the Fargo and Lamoure types are well supplied with lime thruout the soil section, but the soils of the Bremer, O'Neill and Waukesha series on the terraces and of the Wabash series on the bottoms are acid and in need of lime.

TABLE VI. PLANT FOOD IN CARROLL COUNTY, IOWA, SOILS
Pounds per acre of 6 million pounds of subsoil (20"-40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,676	4,140	46,917		4,000
107	Webster silty clay loam	3,798	3,000	41,631	18,662	None
138	Clarion loam	3,432	1,440	112,949	15,919	None
55	Webster loam	2,988	5,880	75,355	2,609	None
149	Clarion fine sandy loam	3,312	3,240	138,828	14,892	None
4	Carrington fine sandy loam	2,301	5,280	40,495		4,000
191	Pierce sandy loam	3,069	120	138,933	17,733	None
	LOESS SOILS					
9	Marshall silt loam	3,494	4,620	49,413		5,000
	TERRACE SOILS					
109	Fargo silty clay loam	4,725	11,940	161,467	4,525	None
108	O'Neill loam	2,949	1,590	21,509		2,000
152	Fargo silt loam	3,030	4,500	58,245	13,338	None
88	Bremer silt loam	2,745	4,200	51,294		2,000
110	O'Neill fine sandy loam	3,354	1,500	19,806		None
75	Waukesha silt loam	2,988	4,380	51,049		6,000
43	Bremer silty clay loam	4,404	8,400	138,133		2,000
146	O'Neill fine sand	2,667	2,340	25,179		3,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	5,475	16,080	174,131		2,500
26a	Wabash silt loam (colluvial phase)	4,887	11,280	114,370		6,000
111	Lamoure silty clay loam	3,675	4,080	58,448	15,098	None
48	Wabash silty clay loam	3,513	4,800	68,535		None
49	Wabash loam	3,918	6,000	74,771		None

Greenhouse Experiments

Two greenhouse experiments were carried out on the soils from Carroll County in order to secure some information on the fertilizer needs of the soils and of the value of certain fertilizer treatments. These experiments were carried out on the Carrington loam and the Marshall silt loam, the two most important types in the county.

The fertilizer treatments employed included the application of manure, lime,

Fig. 3. Clover in greenhouse experiment on Carrington loam, Carroll County.

Fig. 4. Clover in greenhouse experiment on Marshall silt loam, Carroll County.

rock phosphate, superphosphate, a complete commercial fertilizer and muriate of potash. Manure was added at the rate of 8 tons per acre. Lime was supplied in amounts sufficient to correct the acidity of the soil. Superphosphate was added at the rate of 200 pounds per acre and muriate of potash at the rate of 50 pounds per acre. Wheat and clover were grown in the pots, the clover being seeded about one month after the wheat was up.

THE RESULTS ON THE CARRINGTON LOAM

The results secured in the experiment on the Carrington loam from Carroll County are given in table VII. The application of manure increased the yields of both the wheat and the clover to a very appreciable extent. The superphosphate alone increased the yield of wheat but showed no effect on the clover and had less effect than the manure alone in the case of the wheat crop. The manure and superphosphate together brought about a large increase in the yield of wheat and a very pronounced increase in the yield of clover. Lime with the superphosphate showed a very beneficial effect on both crops. Manure and lime and superphosphate increased the yield of wheat and clover in a very pronounced way. Muriate of potash with the manure, lime and superphosphate showed no effect on either crop.

THE RESULTS ON THE MARSHALL SILT LOAM

The results secured in the experiment on the Marshall silt loam from Carroll County are given in table VIII. The application of manure almost doubled the yield of wheat in this test and brought about a very large increase in the yield of

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, CARROLL COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	10.6	75.0
2	Manure	14.4	85.8
3	Superphosphate	11.4	69.3
4	Manure + superphosphate	18.1	99.9
5	Limestone + superphosphate	12.1	100.4
6	Manure + limestone + superphosphate	17.7	100.5
7	Manure + limestone + superphosphate + potassium	16.2	94.8

TABLE VIII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, CARROLL COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	7.6	54.3
2	Manure	14.5	86.8
3	Superphosphate	8.6	73.3
4	Manure + superphosphate	17.2	113.0
5	Limestone + superphosphate	11.5	89.3
6	Manure + limestone + superphosphate	17.9	131.1
7	Manure + limestone + superphosphate + potassium	16.9	108.9

clover. Superphosphate increased both crops to a lesser extent than did the manure. Manure and superphosphate together showed a considerable increase in the yield of wheat and also in the yield of clover. Lime and superphosphate had a greater effect than the superphosphate but a much less effect than the manure and superphosphate. Manure with the lime and superphosphate showed the largest influence on both crops, bringing about a very large increase in the yield of clover. Muriate of potash with the manure, lime and superphosphate showed no effect on either of the crops grown.

Field Experiments

There are no field experiments located in Carroll County, but a number of tests have been under way in other counties for a period of years. As these tests are located on the same soil types the results will be given in this report since they indicate fairly accurately the results which may be secured in Carroll County. Experiments on the Carrington loam on the Scranton Field in Greene County, on the Carrington loam on the Jewell Field in Hamilton County, on the Carrington loam on the Pilot Mound Field in Boone County, and on the Carrington loam

Fig. 5. Wheat and clover on Marshall silt loam from Carroll County, greenhouse experiment.

Fig. 6. Wheat and clover on Carrington loam from Carroll County, greenhouse experiment.

on the Dallas Center Field in Dallas County, on the Marshall silt loam on the Lawton Field in Woodbury County, on the Marshall silt loam on the Cherokee Field in Cherokee County, on the Marshall silt loam on the Avoca Field in Pottawattamie County and on the Webster silty clay loam on the Newell Field in Buena Vista County are included.

These experiments are planned to determine the value of various soil treatments and are laid out on land that is representative of particular soil types. Part of the fields include 13 plots, 155 feet 7 inches by 29 feet, or one-tenth of an acre in size, and the remainder are made up of nine plots of the same size. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops to insure accurate results.

On the experimental fields where the 13 plot series is employed, tests are carried out under both the livestock and grain systems of farming. In the former manure is applied as the basic treatment, while in the latter crop residues are employed to supply the organic matter. In the fields where the nine plot series is used, only the livestock system of farming is followed and manure is the basic treatment. The other fertilizing materials tested include limestone, rock phosphate, superphosphate, muriate of potash and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residue treatment consists of plowing under the cornstalks which have been cut with a disc or stalk-cutter and plowing under at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is applied in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in a four-year rotation. Until 1925, rock phosphate was applied at the rate of 2,000 pounds per acre once in four years. Superphosphate is added at the

rate of 120 pounds of the 20 percent material per acre annually three years out of four in a four-year rotation. Until 1923 this material was applied at the rate of 200 pounds of the 16 percent material per acre annually. From 1923 to 1929, 150 pounds of the 16 percent material was applied annually three years out of four in the rotation. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. The new standard 2-12-2 was employed from 1923 to 1929, being applied at the rate of 200 pounds per acre annually, thus applying the same amount of phosphorus as is contained in the superphosphate. Beginning in 1929, for the Marshall and Carrington soils a 2-12-6 fertilizer is being employed, and on the Webster types a 2-16-2 fertilizer is being used, the proper amount of these fertilizers being applied to add as much phosphorus as is supplied in 120 pounds of 20 percent superphosphate. Muriate of potash is employed at the rate of 50 pounds per acre three years out of four in the four-year rotation.

THE SCRANTON FIELD

The results secured on the Carrington loam on the Scranton Field in Greene County are given in table IX. The application of manure increased the crop yields in every season, the largest beneficial effects being shown on the corn in 1927 and 1928 and on the oats in 1929. The addition of lime with the manure increased the crops in most cases. There was no effect on the oats in 1923 and 1926. In all other cases the gains from lime were quite definite.

The rock phosphate with the manure and lime increased the crop yields in practically all seasons, but in most cases the gains were not very large. The corn in 1925 and the oats in 1926 showed the greatest effect. The superphosphate with the manure and lime brought about larger effects than the rock phosphate in the case of the oats in 1923, the corn in 1924 and 1925 and the oats in 1929. In the

TABLE IX. FIELD EXPERIMENT, CARRINGTON LOAM, GREENE COUNTY, SCRANTON FIELD, SERIES I

Plot No.	Treatment	1923 Oats bu. per A.	1924 Corn bu. per A. (1)	1925 Corn bu. per A.	1926 Oats bu. per A. (2)	1927 Corn bu. per A.	1928 Corn bu. per A.	1929 Oats bu. per A.
1	Check	59.0	38.0	50.8	35.4	41.5	59.8	52.3
2	Manure	63.5	42.8	54.1	35.7	46.7	64.5	71.5
3	Manure+limestone	63.5	46.2	60.4	35.7	53.4	69.3	74.9
4	Manure+limestone+rock phosphate	63.5	44.3	63.1	39.5	54.1	70.9	74.9
5	Check	55.5	36.3	50.2	34.0	44.6	58.1	64.6
6	Manure+limestone+superphosphate	72.5	48.4	66.7	.....	50.2	67.7	85.1
7	Manure+limestone+superphosphate +potassium	74.8	50.8	62.2	39.2	50.9	68.8	87.3
8	Manure+limestone+complete commercial fertilizer	82.7	51.6	59.9	39.7	52.0	68.5	85.1
9	Check	61.2	33.1	51.6	33.2	48.1	57.6	66.1
10	Superphosphate	.....	.....	.....	46.3	49.0	61.9	85.1

(1) Cattle and hogs were turned into field a few days before plots were harvested, which affected the yields to some extent.

(2) Plot 6 sample lost. Plot 10 added this year with superphosphate alone.

other seasons the rock phosphate gave slightly larger effects. The muriate of potash with the superphosphate, manure and lime showed small increases in most seasons. The differences were not large, however, in any case. The complete commercial fertilizer with the manure and lime brought about larger effects than the superphosphate on the corn in 1924, 1927 and 1928, and on the oats in 1923 but had less effect on the corn in 1925. In most instances the differences were not very great.

THE JEWELL FIELD

The results secured on the Carrington loam on the Jewell Field in Hamilton County are given in table X. The application of manure increased the crop yields in every season, showing the largest effect on the corn in 1929. Lime with manure gave beneficial effects on the corn in 1926 and 1929 and on the oats in 1928. It showed no influence on the corn in 1927. The beneficial effects were large in 1926 and in 1928.

The rock phosphate with the manure and lime showed a beneficial effect on the corn in 1926 and 1927 but had no effect on the crops in 1928 and 1929. The superphosphate with the manure and lime showed no effect on the corn in 1926 or the oats in 1928, had little effect on the corn in 1927 but showed a distinct influence on the corn in 1929. The muriate of potash with the manure, lime and superphosphate increased the crop yields in every case, showing very large effects on the oats in 1928. The increases in the corn crop in 1926 and 1927 were quite definite. The complete commercial fertilizer with the manure had a greater effect than the superphosphate on the corn in 1926 but showed less effect in the other seasons.

THE PILOT MOUND FIELD

The results secured on the Carrington loam on the Pilot Mound Field in Boone County are given in table XI. The application of manure increased the crop yields on this soil in all but one season. The largest beneficial effects

TABLE X. FIELD EXPERIMENT, CARRINGTON LOAM, HAMILTON COUNTY, JEWELL FIELD, SERIES I

Plot No.	Treatment	1925 Timothy and clover tons per acre (1)	1926 Corn bu. per acre	1927 Corn bu. per acre	1928 Oats bu. per acre	1929 Corn bu. per acre (2)
1	Check	----	36.0	51.1	35.2	52.5
2	Manure	----	39.2	54.0	49.9	62.4
3	Manure + limestone	----	47.6	51.9	58.9	63.3
4	Manure + limestone + rock phosphate	----	48.0	57.7	52.2	60.5
5	Check	----	35.6	55.2	49.9	52.0
6	Manure + limestone + superphosphate	----	42.8	54.3	51.0	65.5
7	Manure + limestone + superphosphate + potassium	----	49.2	56.1	64.7	66.0
8	Manure + limestone + complete commercial fertilizer	----	49.6	49.9	48.8	64.8
9	Check	----	41.2	43.1	46.5	48.6

(1) Plots were pastured, no results.
(2) Yield on a 15 percent moisture basis.

TABLE XI. FIELD EXPERIMENT, CARRINGTON LOAM, BOONE COUNTY, PILOT MOUND FIELD, SERIES I

Plot No.	Treatment	1922 Oats bu. per A.	1923 Corn bu. per A.	1924 Oats bu. per A.	1925 Sweet Clover tons per A. (1)	1926 Corn bu. per A.	1927 Corn bu. per A.	1928 Oats bu. per A. (2)	1929 Sweet Clover tons per A. (3)
1	Check	33.4	59.9	43.5	.....	52.8	48.3	77.1	1.27
2	Manure	37.8	64.4	50.8	.....	59.7	51.9	74.9	1.74
3	Manure+limestone	44.8	60.4	58.1	.....	60.8	53.9	72.6	1.46
4	Manure+limestone+rock phosphate	45.1	64.4	68.2	.....	53.8	54.6	74.9	1.68
5	Check	35.4	56.0	46.8	.....	45.8	41.8	61.3	1.26
6	Manure+limestone+super-phosphate	50.0	61.8	57.0	.....	55.4	66.9	77.1	1.33
7	Manure+limestone+super-phosphate+potassium	59.4	68.5	66.8	.....	58.6	65.2	74.9	2.09
8	Manure+limestone+complete commercial fertilizer	71.7	59.9	66.1	.....	50.6	63.5	77.1	1.57
9	Check	36.3	59.8	46.8	.....	49.1	54.1	58.9	1.11

(1) Field was pastured, no results taken.
(2) Unable to account for high yield on plot 1.
(3) Plots damaged by late fall and early spring pasturing.

appeared on the oats in 1924 and on the sweet clover in 1929. The increases were quite definite also on the various corn crops. Only in 1928 were no increases secured from the use of manure. Lime with the manure increased the crop yields in most cases but no large gains were evidenced. There was no beneficial effect on the clover in 1929 which was somewhat surprising. It seems probable, however, that the yield on plot 2 in that season was abnormal and that the lime really did bring about some beneficial effects.

The rock phosphate with the manure and lime increased the crop yields in all but one season. The increase was very definite in the case of the oats in 1924 and the sweet clover in 1929. The corn in 1926 was not increased, but in all other seasons small increases in crop yields were secured. The superphosphate with the manure and lime showed a greater effect than the rock phosphate in several seasons. The oats in 1922, the corn in 1926 and 1927, the oats in 1928 and the sweet clover in 1929 showed more benefits from the superphosphate. The rock phosphate had larger effects on the corn in 1923 and on the oats in 1924. The largest difference in favor of the superphosphate appeared on the corn in 1927.

The muriate of potash with the manure, lime and superphosphate showed beneficial effects on the crops grown except in the case of the corn in 1927 and the oats in 1928. The largest increase appeared on the sweet clover in 1929, but there were also quite definite increases on the oats in 1922, the corn in 1923 and the oats in 1924. The complete commercial fertilizer with the manure and lime brought about larger increases than the superphosphate in two or three cases. The oats in 1922 and in 1924 and the sweet clover in 1929 showed larger effects from the complete commercial fertilizer than from the superphosphate. In other seasons, however, smaller beneficial effects appeared.

THE DALLAS CENTER FIELD

The results secured on the Carrington loam on the Dallas Center Field in Dallas County are given in table XII. The application of manure increased the crop yields in all but one season, the largest effects appearing on the sweet clover in 1928 and on the corn in 1929. In some cases the increases were not very large. Lime with the manure increased the yields in most cases. The oats in 1927 and the sweet clover in 1928 showed no effect, but in all other cases gains were noted. The corn was largely increased in 1925, 1926 and 1927, and there was an increase in the wheat in 1923.

The rock phosphate with the manure and lime increased the crop yields in all but one season. The corn in 1929 showed no effect, but with the corn in 1925, the oats in 1927 and particularly the sweet clover in 1928, there were large crop increases. The superphosphate with the manure and lime had a larger influence than the rock phosphate in several cases, as on the wheat in 1923, the sweet clover in 1928 and the corn in 1929. In the case of the other crops, however, no superior value for the superphosphate was indicated, and in the case of the corn in 1926 and the oats in 1927, the rock phosphate had the largest influence. The complete commercial fertilizer with the manure and lime had slightly less effect than the superphosphate in all but two cases. With the oats in 1927 and the sweet clover in 1928, the complete commercial fertilizer was superior to the superphosphate, but in all other cases the results with the superphosphate were somewhat better. The differences except for the sweet clover in 1928 were not very large.

THE LAWTON FIELD

The results secured in the field experiments on the Marshall silt loam on the Lawton Field, in Woodbury County, are given in table XIII. The application of manure increased the corn yields in 1925 and 1926 but showed no effect on the

TABLE XII. FIELD EXPERIMENT, CARRINGTON LOAM, DALLAS COUNTY, DALLAS CENTER FIELD, SERIES I

Plot No.	Treatment	1923 Winter Wheat bu. per A.	1924 Clover tons per A. (1)	1925 Corn bu. per A.	1926 Corn bu. per A.	1927 Oats bu. per A.	1928 Sweet Clover tons per A. (2)	1929 Corn bu. per A. (3)
1	Check	24.8	.....	50.3	69.9	52.6	1.81	69.0
2	Manure	25.9	.....	51.2	73.0	51.7	2.00	75.4
3	Manure+limestone	29.6	.....	54.1	78.9	50.2	1.97	79.2
4	Manure+limestone+rock phosphate	30.9	.....	58.8	79.2	68.2	2.29	78.3
5	Check	21.8	.....	51.9	76.0	53.4	1.78	69.1
6	Manure+limestone+superphosphate	33.8	.....	58.8	76.8	64.3	2.42	82.2
7	Manure+limestone+superphosphate +potassium	34.5	.....	59.6	78.9	62.4	2.17	80.4
8	Manure+limestone+complete commercial fertilizer	30.4	.....	59.5	73.6	64.4	2.69	80.2
9	Check	20.6	.....	53.3	65.3	46.3	1.65	74.1

(1) Field was pastured, no results.
(2) Total of two cuttings.
(3) Yield on 15 percent moisture basis.

TABLE XIII. FIELD EXPERIMENT, MARSHALL SILT LOAM, WOODBURY COUNTY, LAWTON FIELD, SERIES I

Plot No.	Treatment	1925 Corn bu. per acre	1926 Corn bu. per acre	1927 Oats bu. per acre	1928 Corn bu. per acre (1)	1929 Corn bu. per acre (2)
1	Check	28.6	34.8	60.3	----	44.5
2	Manure	40.2	37.2	59.4	----	44.1
3	Manure + limestone	45.8	38.8	50.1	----	45.8
4	Manure + limestone + rock phosphate	30.3	40.2	61.5	----	45.8
5	Check	29.1	37.4	44.1	----	42.4
6	Manure + limestone + superphosphate	37.6	40.2	52.5	----	46.9
7	Manure + limestone + superphosphate + potassium	35.0	41.0	58.8	----	49.5
8	Manure + limestone + complete commercial fertilizer	38.5	39.0	67.9	----	46.5
9	Check	31.8	34.0	52.1	----	40.5

(1) Corn seriously damaged by hot winds in July at tasseling time, resulting in very small corn which was all blown off with a heavy wind in October, no results.
(2) Corn damaged by dry weather in August.

oats in 1927 or the corn in 1929. Limestone with the manure increased the yields of corn in every case but showed no effect on the oats. The rock phosphate with the manure and lime brought about a very large increase in the oats in 1927 and showed a small effect on the corn in 1926. No effect was evidenced in 1925 or in 1929. The superphosphate with the manure and lime showed slightly larger effects than the rock phosphate in the case of the corn in 1925 and 1929 but had no greater effect in 1926. It showed a smaller influence than the rock phosphate on the oats in 1927. The use of muriate of potash with the manure, lime and superphosphate showed some indications of value in the case of the oats in 1927 and the corn in 1929 but had a very slight effect on the corn in 1926. The complete commercial fertilizer with the manure and lime showed a very much larger effect than the superphosphate on the oats in 1927 but had no greater effect in the other seasons.

THE CHEROKEE FIELD

The results secured on the Marshall silt loam on the Cherokee Field in Cherokee County are given in table XIV. The application of manure increased the crop yields to a very pronounced extent in all but one season. Lime with the manure increased the yields of all the crops grown. It showed very definite effects on the corn and small grain crops as well as on the clover and timothy. The rock phosphate with the manure and lime gave increases on the crops in practically all seasons. The clover and timothy in 1925 and the corn in 1928 showed no beneficial effects, but the oats in 1924 were increased to a very pronounced extent. There was also a definite increase in this crop in 1929.

The superphosphate with the manure and lime showed a larger effect than the rock phosphate in all seasons except 1928. In some cases very considerable differences were shown, as for example, on the clover and timothy in 1925, and on

TABLE XIV. FIELD EXPERIMENT, MARSHALL SILT LOAM, CHEROKEE COUNTY, CHEROKEE FIELD, SERIES I

Plot No.	Treatment	1922 Corn bu. per A.	1923 Corn bu. per A.	1924 Oats bu. per A.	1925 Clover and Timothy tons per A.	1926 *Corn bu. per A.	1927 *Corn bu. per A.	1928 *Corn bu. per A.	1929 Oats bu. per A.
1	Check	59.8	51.2	49.0	1.87	34.6	47.9	43.5	88.5
2	Manure	64.9	56.1	54.7	2.03	32.8	52.9	45.5	91.8
3	Manure+limestone	66.6	59.8	55.5	2.18	35.2	53.7	49.2	99.8
4	Manure+limestone+rock phosphate	69.8	60.8	60.6	2.16	37.6	54.8	49.1	103.3
5	Manure+limestone+superphosphate	70.8	61.3	61.6	2.37	46.2	57.9	47.2	106.7
6	Manure+limestone+superphosphate+potassium	72.6	61.9	62.0	2.29	49.2	55.7	44.5	102.2
7	Manure+limestone+complete commercial fertilizer	74.2	62.8	70.3	2.38	46.0	49.7	47.3	103.3
8	Check	61.1	52.7	55.2	1.99	36.3	43.6	44.5	90.8
9	Crop residues	63.4	54.5	54.7	2.11	46.4	44.0	46.8	93.1
10	Crop residues+limestone	62.6	58.9	61.6	2.25	46.8	42.7	37.1	84.0
11	Crop residues+limestone+rock phosphate	62.6	60.3	62.7	2.19	45.8	47.7	44.3	93.1
12	Crop residues+limestone+superphosphate	60.4	64.7	66.7	2.32	44.8	46.4	44.9	90.8
13	Crop residues+limestone+superphosphate+potassium	50.8	66.7	63.2	2.47	46.6	47.9	44.4	88.5
14	Crop residues+limestone+complete commercial fertilizer	50.4	66.2	68.6	2.33	44.2	49.2	44.5	96.4
15	Check	53.9	52.3	49.7	1.92	45.6	42.7	37.4	83.2

*Bindweed damaged plots considerably; yields are not representative.

the corn in 1926. The muriate of potash with the manure, lime and superphosphate showed very slight beneficial effects in one or two seasons but in most cases had no influence. The complete commercial fertilizers with the manure and lime brought about almost the same effects as the superphosphate. There was no superiority evidenced for the complete fertilizer.

The crop residues had very little influence on the yields, showing small increases in one or two instances. Lime with the crop residues gave increases in most cases. It had the largest effect on the clover and timothy in 1925. The rock phosphate with the crop residues and lime gave small increases in several seasons. It had the largest effect on the corn in 1927 and on the oats in 1929. The superphosphate with the crop residues and lime showed a slightly greater effect than the rock phosphate in two or three cases, especially on the clover and timothy in 1925, but in several seasons it had less effect than the rock phosphate. The muriate of potash with the residues, lime and superphosphate showed very slight beneficial effects in one or two cases, but in most seasons it had no influence whatever. The complete commercial fertilizer with the crop residues and lime, gave about the same effects as did the suprphosphate, showing up slightly better on the corn in 1927 and on the oats in 1929. In most cases the superphosphate gave quite as satisfactory results.

THE AVOCA FIELD

The results secured on the Marshall silt loam on the Avoca Field in Pottawattamie County, are given in table XV. The beneficial effect of manure on this soil is shown in practically all cases. The influence on the oats may be noted particularly and also the large effects on the clover and sweet clover. The corn yields in 1926 and 1929 were very largely increased by the addition of manure. In other years the effects on the corn were much smaller. The influence of lime was evidenced particularly on the sweet clover crop in 1924, on which a very large increase in yield resulted from the application. There was also an effect noted on the oats in 1927. No beneficial effects were shown on the clover crop in 1921.

The application of rock phosphate and superphosphate along with the manure and lime showed large beneficial effects on the crops grown in some seasons. The corn in 1919, 1922 and 1928 showed pronounced effects from the use of superphosphate and slightly less effects from the rock phosphate. There was considerable influence from both phosphates on the oats in 1923 and a large effect in 1927. The crop in 1920 was not materially benefited. No effects from the phosphates were evidenced on the clover crops in 1921 and 1924. The complete commercial fertilizer had about the same effect as the phosphates on most of the crops grown. In some cases it showed a slightly larger influence, as on the sweet clover

TABLE XV. FIELD EXPERIMENT, MARSHALL SILT LOAM, POTTAWATTAMIE COUNTY, AVOCA FIELD, SERIES I, FIELD II

Plot No.	Treatment	1919 Corn bu. per A. (1)	1920 Oats bu. per A. (2)	1921 Clover tons per A. (3)	1922 Corn bu. per A. (4)	1923 Oats bu. per A.	1924 Sweet Clover tons per A. (5)	1925 Corn bu. per A.	1926 Corn bu. per A.	1927 Oats bu. per A.	1928 Corn bu. per A.	1929 Corn bu. per A. (6)
1	Check	72.9	62.2	2.0	58.1	48.7	0.36	62.2	54.6	45.7	64.5	59.4
2	Manure	72.1	69.0	2.7	53.6	56.7	0.63	63.9	63.7	56.0	67.5	70.4
3	Manure+lime	74.0	72.3	2.6	53.9	53.2	1.82	61.6	64.0	64.0	68.3	71.1
4	Manure+lime+rock phosphate	77.8	58.8	2.7	55.5	60.0	1.52	58.1	61.3	69.8	66.4	73.3
5	Manure+lime+superphosphate	79.3	69.0	2.5	56.5	60.0	1.68	52.3	64.8	75.0	70.9	71.5
6	Manure+lime+complete commercial fertilizer	77.5	61.2	2.8	57.5	66.8	1.92	51.4	65.6	79.1	65.6	70.6
7	Check	71.5	56.8	2.0	44.8	47.6	0.85	39.8	61.0	50.0	64.3	61.3
8	Crop residues *	78.9	63.9	2.0	44.8	49.8	0.90	51.0	66.4	57.1	66.7	68.2
9	Crop residues+lime	80.7	68.1	2.1	50.0	56.7	1.92	58.7	64.5	66.7	66.4	59.8
10	Crop residues+lime+rock phosphate	78.5	68.6	2.8	54.8	59.0	1.83	56.8	69.6	66.6	62.1	66.2
11	Crop residues+lime+superphosphate	81.1	75.1	2.2	54.1	64.5	1.50	57.1	66.6	64.7	66.1	66.7
12	Crop residues+lime+complete commercial fertilizer	80.4	68.6	2.9	52.0	52.1	1.44	58.4	65.8	70.0	64.8	66.6
13	Check	80.0	68.6	2.2	46.3	50.9	1.12	51.8	60.8	60.6	61.6	62.2

*Superphosphate added annually since 1925.
(1) Field slopes toward plot 13.
(2) Not limed until Oct. 1, 1920; 3 tons per acre.
(3) Field pastured until June 1.
(4) Corn injured by hail in August and by rainy spring.
(5) Strong winds and wireworms cut down stand considerably.
(6) Yield on a 15 percent moisture basis.

in 1924 and on the oats in 1927. In other years, as on the corn in 1928, there was less influence from the complete fertilizer.

The crop residue treatment generally had a small influence. Lime with the crop residues increased the crop yields with the exception of the corn crops in 1926 and 1928. The largest influence of the lime was evidenced on the sweet clover in 1924. Considerable increases were noted, however, on the corn in 1922, on the oats in 1923 and on the corn in 1925. The rock phosphate and superphosphate brought about increases in crop yields in several cases, the effect of the superphosphate being particularly evidenced in 1920 and in 1923. The effects on the corn crop were not large for either of the phosphates. The complete commercial fertilizer had about the same effect as the superphosphate except on the oats in 1927 where a large influence was noted, and on the clover in 1921 where it brought about a greater effect.

THE STORM LAKE FIELD

The results secured in the experiment on the Webster silty clay loam on the Storm Lake Field in Buena Vista County are given in table XVI. Manure brought about beneficial effects on the various crops grown, showing up particularly well on the clover and on the alfalfa. The increase in the alfalfa crop in 1929 was extremely large. Considerable gains were noted also in the case of some of the corn crops and with the barley in 1925. The soil was not acid and hence

TABLE XVI. FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY, STORM LAKE FIELD

Plot No.	Treatment	1918 Oats bu. per A. (1)	1919 Corn bu. per A.	1920 Corn bu. per A.	1921 Oats bu. per A.	1922 Clover tons per A. (2)	1923 Corn bu. per A. (3)	1924 Corn bu. per A. (4)	1925 Barley bu. per A.	1926 Corn bu. per A.	1927 Oats bu. per A.	1928 Alfalfa tons per A. (5)	1929 Alfalfa tons per A. (5)
1	Check	73.0	54.7	48.2	45.1	0.75	51.0	22.7	40.9	50.4	54.5	3.11	3.51
2	Manure	73.0	54.1	57.3	42.2	1.01	60.7	27.5	47.8	50.1	50.5	3.45	4.99
3	Manure+superphosphate+potassium chloride	73.0	57.6	58.1	36.3	1.29	65.1	29.2	56.9	53.6	53.0	4.13	5.31
4	Manure+rock phosphate	80.6	61.1	64.2	43.8	1.26	66.4	31.0	61.8	48.5	53.2	4.62	5.44
5	Manure+superphosphate	74.5	66.4	76.5	51.8	1.42	68.5	31.8	57.6	58.4	51.7	4.12	5.37
6	Manure+complete commercial fertilizer	82.0	61.1	80.0	43.8	1.43	66.8	33.9	60.7	52.8	52.5	4.56	5.78
7	Check	70.0	71.5	66.6	40.9	1.10	55.8	34.0	44.5	48.5	54.5	3.88	4.08
8	Crop residues	85.1	75.7	67.7	49.1	1.08	63.3	37.3	44.5	51.2	47.4	4.35	4.44
9	Crop residues+superphosphate+potassium chloride	76.0	70.1	67.2	41.1	1.25	70.7	35.7	64.4	52.8	51.2	5.08	5.54
10	Crop residues+rock phosphate	79.0	70.4	76.2	41.6	1.20	63.2	27.4	52.8	50.1	54.5	4.60	4.93
11	Crop residues+superphosphate	73.0	64.0	76.2	45.5	1.23	63.1	31.1	58.2	49.6	47.0	4.81	5.56
12	Crop residues+complete commercial fertilizer	85.1	67.5	76.2	43.8	1.13	61.3	27.2	58.1	43.5	61.9	4.45	5.07
13	Check	79.0	67.5	67.7	39.7	0.86	51.9	23.1	41.6	34.9	49.5	2.52	3.13

(1) Soil basic; no manure added; oats badly lodged.
(2) Superphosphate and potassium chloride (50 pounds per acre) applied to 3 and 9 in 1922; first crop only.
(3) Hogs in corn damaged yield.
(4) Early frost left corn very chaffy and light and practically none was marketable.
(5) Total of 3 cuttings.

no lime was applied. The use of rock phosphate and superphosphate with the manure brought about increases in crop yields in all cases, the effect being particularly large with the superphosphate on the corn in 1920, on the clover in 1922 and on the corn in 1926. The rock phosphate generally showed less effect than the superphosphate. The reverse was the case, however, with the oats in 1918 and 1927, the barley in 1925 and the alfalfa in 1928 and 1929.

The complete commercial fertilizer gave slightly larger influences than the superphosphate in several seasons, but in other cases the beneficial effects were not as large. In no case was there any considerable difference between the effects of these materials. The largest difference occurred on the alfalfa in 1929. The muriate of potash applied with superphosphate to plot 3 showed no beneficial effect.

The crop residues had little influence on the yields on this soil. The rock phosphate and the superphosphate applied with the residues brought about increases in yields which were quite definite in some cases, particularly on the corn in 1930. In several cases, however, the phosphates did not seem to show especially large effects when applied without farm manure. The complete commercial fertilizer brought about larger effects than the superphosphate in several cases, but in other instances it had less value. The muriate of potash applied with the superphosphate to plot 9, showed small crop increases in every season. It had a large effect on the alfalfa in 1928.

THE NEWELL FIELD

The results secured in the field experiment on the Webster silty clay loam on the Newell Field in Buena Vista County are given in table XVII. The application of manure brought about large crop increases in all but one season, 1926, when the yields were abnormal due to hot, dry weather. The effects of the manure were evidenced on the corn and oats but particularly on the clover. Lime with manure gave slight increases in crop yields in several cases. The effects were not large, however, and as this soil is only slightly acid and the acidity is confined to the surface soil, no large effect from the use of lime would be expected.

The rock phosphate and the superphosphate brought about increases in crop yields in practically all seasons. There were one or two exceptions but in these cases the differences were slight. The effects of the two materials were particularly evidenced on the clover in 1925, on the corn in 1926, and in the case of the superphosphate, on the alfalfa in 1929. The superphosphate also had a large effect on the clover in 1921. The influence on the corn in 1922 and on the oats in 1920 was quite evident. In most cases the superphosphate seemed to be somewhat preferable to the rock phosphate. There were one or two exceptions, however. In 1918, 1923 and 1926 the rock phosphate gave better yields than the superphosphate. The complete commercial fertilizer showed slightly larger effects than the superphosphate in one or two cases, but in general the superphosphate gave quite as large or even larger increases in yields when used with manure and lime; hence it should be considered preferable for application to this soil.

The crop residues had little effect on the yields on this soil, as would be ex-

TABLE XVII. FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY, NEWELL FIELD, SERIES I

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Corn bu. per A. (1)	1920 Oats bu. per A. (1)	1921 Clover tons per A.	1922 Corn bu. per A.	1923 Corn bu. per A.	1924 Oats bu. per A. (2)	1925 Clover tons per A. (3)	1926 Corn bu. per A. (4)	1927 Corn bu. per A. (5)	1928 Oats and Barley bu. per A. (6)	1929 Alfalfa tons per A. (7)
1	Check	69.0	44.8	56.7	0.53	68.7	59.2	.....	1.70	51.2	45.7	.....	4.71
2	Manure	70.9	49.1	64.1	0.60	70.5	65.6	.....	1.97	31.4	50.5	.....	4.81
3	Manure+limestone	71.4	54.4	63.5	0.70	69.9	68.3	59.8	1.95	23.5	50.2	.....	4.84
4	Manure+limestone+rock phosphate	74.1	61.4	69.7	0.70	74.1	69.3	63.5	2.04	46.4	31.4	.....	4.36
5	Manure+limestone+superphosphate	66.9	65.1	76.3	1.13	80.0	63.4	65.5	2.36	36.3	37.4	.....	5.57
6	Manure+limestone+complete commercial fertilizer	66.4	70.9	68.9	1.20	74.4	67.7	72.2	2.22	28.3	50.6	.....	5.09
7	Check	60.9	62.4	59.4	0.58	66.9	55.0	62.3	1.35	45.9	31.1	.....	2.24
8	Crop residues	62.9	56.1	59.4	0.50	63.6	56.4	66.5	1.10	52.3	33.2	.....	2.05
9	Crop residues+limestone	64.6	59.2	61.4	0.43	64.2	59.5	71.8	1.21	57.6	41.7	.....	2.34
10	Crop residues+limestone+rock phosphate	63.4	60.8	56.7	0.53	67.3	65.9	66.9	1.88	50.1	40.5	.....	3.16
11	Crop residues+limestone+superphosphate	62.4	68.5	72.0	0.90	67.3	64.1	69.3	2.08	58.6	52.1	.....	4.19
12	Crop residues+limestone+complete commercial fertilizer	61.3	65.3	71.3	0.93	67.0	65.8	.....	2.29	47.5	48.5	.....	4.71
13	Check	59.4	65.3	60.1	0.58	66.2	60.9	.....	1.78	54.9	45.5	.....	2.44

(1) No limestone applied to plots until the fall of 1920.
(2) Plots 1, 2, 12 and 13 cut before field man arrived at field.
(3) Mixture of red clover and biennial white sweet clover.
(4) Corn cut early due to hot dry season, average moisture content 37.5 percent which accounts for varying yields.
(5) Corn replanted due to damage by alkali; second planting also damaged. Corn immature when frost came; high moisture content accounts for varying yields.
(6) Mixture of oats and barley grown; no attempt to figure yield in bushels per acre.
(7) Low wet area on plots 1, 2 and 3 responsible for high yields, also high alkali content on these plots which seemed to favor the growth of alfalfa. Total of 3 cuttings.

pected. Lime with the residues gave slight increases in yields in several cases. The differences were not large, however, but were sufficient to show the desirability of applying lime to this soil when it is acid. The rock phosphate, the superphosphate and the complete commercial fertilizer showed beneficial effects in some cases on the various crops grown. In other instances, however, no effects were evidenced. The clover in 1925 showed particularly large effects from the use of a phosphate material. The alfalfa yield in 1929 was also increased to a very large extent. In 1921, the clover was increased by the superphosphate and the complete commercial fertilizer. These fertilizers increased the oat yields to a large extent in 1920 and had a beneficial effect on the corn in 1919. In some other seasons, as in 1922 and 1923, the three materials gave practically identical effects, all showing increases over the crop residues and lime alone.

THE NEEDS OF CARROLL COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

Some general indications regarding the needs of the soils of Carroll County, have been secured from the laboratory, greenhouse and field tests discussed

in the previous pages. It is possible, therefore, to offer some suggestions regarding the best methods of treatment for the soil types in this county. Definite recommendations cannot be made for all of the soil conditions, but some of the general suggestions may be put into effect on any farm. No recommendations are made except such as have been proved to be of value thru practical experience.

It is suggested that tests be carried out under individual farm conditions in the case of certain fertilizer treatments. Such tests are easily made. Many farmers are securing excellent data in this way and are finding the results of large value to them in their farming operations. The results are also frequently of large value to other farmers who are located on the same soil types. Directions which may be followed in carrying out simple experiments along these lines are given in Circular 97 of the Iowa Agricultural Experiment Station. The Soils Section of the Experiment Station will aid and advise any farmer who may be interested in carrying out fertilizer tests on his own soils.

Manuring

Most of the soils in Carroll County are very well supplied with organic matter as is indicated by their dark color. This is especially true of the Webster types on the drift uplands, the Fargo and Bremer soils on the terraces and the Wabash and Lamoure soils on the bottoms. The Carrington loam and the Clarion loam on the drift uplands and the Marshall silt loam on the loessial uplands are fairly well supplied. The Clarion fine sandy loam, the Carrington fine sandy loam and the Pierce sandy loam on the drift uplands, however, are rather low in this constituent. On these latter soils applications of fertilizing materials supplying organic matter are necessary now. On all the types, however, some materials adding organic matter must be used regularly if the supply is to be kept up.

The application of farm manure is particularly desirable on the light colored soils and on those types which are sandy in texture, in order to build up the content of organic matter and make the soils more productive. On the Clarion fine sandy loam, the Carrington fine sandy loam and the Pierce sandy loam on the uplands, and on the O'Neill loam, fine sandy loam and fine sand on the terraces, farm manure would have especially large effects. In the experiments which have been discussed earlier, farm manure has been found to be of value also on the Marshall silt loam, on the Carrington loam and even on the Webster silty clay loam. On the latter type and also in the case of the Fargo and Bremer soils on the terraces, small applications of farm manure are of considerable value as a means of stimulating the production of available plant food. Large applications should not be made to these soils as there is danger of causing the small grain crops to lodge. On the light colored sandy soils liberal applications of farm manure are recommended, and regular applications are very desirable.

Green manuring with legumes is frequently a desirable farm practice to aid in the maintaining of the supply of organic matter in the soil. By the use of legumes in this way, it is possible to keep up the nitrogen supply as well as the organic matter content. On grain farms the practice of green manuring is necessary, and on many livestock farms there is an insufficient supply of manure to meet

the needs of all the soils. In such cases green manuring is a desirable practice. On the lighter colored sandy types in Carroll County, green manuring would be of particularly large value. It would also prove beneficial on the Marshall silt loam, the Carrington loam and the Clarion loam, and on the O'Neill types on the terraces. Precautions should always be followed when green manuring is practiced as undesirable results may occur if the conditions in the soil do not permit the proper decomposition of the green material.

The thoro utilization of all crop residues on the farm will aid materially in maintaining the supply of organic matter in the land. These materials should not be burned or otherwise destroyed because of their large fertility value. On livestock farms the residues may be used for feed or bedding and returned to the land with the manure. On the grain farms the materials may be applied directly to the soil or stored and permitted to decompose partially before application.

The beneficial effects of manure on some of the soil types in Carroll County have been indicated in experiments discussed earlier in this report. Experiences of many farmers bear out the results secured in this connection. There is also considerable evidence in the practical experience of farmers of the value of leguminous crops as green manures. For the best crop yields on the soils of this county and for permanent fertility, the proper use of farm manure, crop residues and green manures is very desirable.

The Use of Commercial Fertilizers

The soils of Carroll County are not high in phosphorus, and applications of a fertilizing material supplying this element are needed in many cases at the present time. Some of the darker colored, heavier soils are richer in this element than are the light colored sandy types, but in none of the soils is there a sufficiently large content to insure the proper supplying of phosphorus to crops for a long period of time. On some of the soils, such as the Clarion and Carrington fine sandy loams and the O'Neill soils on the terraces, the use of a phosphorus fertilizer is very desirable at the present time. On the Carrington and Clarion loams the experimental results have shown the application of a phosphate fertilizer to be of large value. Even on the Webster silty clay loam, one of the richest soils in the county, the application of a phosphate fertilizer has proven profitable.

Phosphorus may be supplied to the soils either by the use of rock phosphate or superphosphate. In the former the element phosphorus is slowly made available in the soil, while in the superphosphate it is in a form immediately available for crop use. The superphosphate is more expensive but it usually gives quicker returns and applications are smaller. This material is applied, ordinarily, at the rate of 150 to 200 pounds per acre annually, while the rock phosphate is applied at the rate of 1,000 to 2,000 pounds per acre once in a four-year rotation.

In the tests which have been carried out in the field, both rock phosphate and superphosphate have been employed. In some cases the rock phosphate has proved superior to the superphosphate, but in most instances the superphosphate has given somewhat better results. It is not possible, therefore, to draw definite conclusions at the present time regarding the relative value of the two phosphates. Apparently the results secured will vary under different farming conditions. On light colored

sandy soils in which the organic matter supply is low, superphosphate will undoubtedly prove preferable, but on dark colored types that are high in organic matter, rock phosphate may be quite as satisfactory. On such soils farmers are urged to test both materials and thus determine for their particular conditions the phosphorus needs of their soils and which phosphate carrier may be applied with greater profit.

Some of the soil types in the county are not rich in nitrogen, and additions of fertilizing materials supplying this element are necessary for the best crop growth at the present time. On all of the soil types in the county, however, nitrogen must be taken into account when systems of permanent fertility are planned. There is a constant loss of this element from the soil by cropping and leaching, and unless some means are taken to keep up the supply, it will soon become deficient. On those types which are not low in nitrogen at the present time, the use of some fertilizing materials supplying nitrogen will be needed in the near future, even if they are not necessary now. The Clarion fine sandy loam, the Carrington fine sandy loam, the Pierce sandy loam and the O'Neill types on the terraces are particularly in need of additions of nitrogen containing fertilizers and will respond in a very profitable way to applications of farm manure or the use of leguminous green manures. Crop yields will also be increased considerably by the use of these materials on the Carrington loam, the Clarion loam and the Marshall silt loam. Some of the terrace types will also respond to this treatment.

The proper use of farm manure aids materially in maintaining the supply of nitrogen in the soil. The utilization of crop residues also aids in keeping up the supply of nitrogen. The use of leguminous crops as green manures is the cheapest and best means of increasing the nitrogen content of the soil. When legumes are inoculated they take a large part of their nitrogen from the atmosphere, and, hence, when turned under in the soil they add considerable nitrogen to the land. On many of the soils of the county, the practice of green manuring may be of large value as a supplement to or substitute for farm manure.

Commercial nitrogenous fertilizers are probably unnecessary for general use on the soils of Carroll County at the present time. The nitrogen supply of these soils may be built up and kept up quite as satisfactorily and probably more economically by the use of leguminous green manures in addition to the proper application of farm manure and crop residues. Small amounts of commercial nitrogen fertilizers may sometimes be used with profit as top-dressings for special crops, but for general farm crops their use probably will not pay.

On the normal soils in the county potassium fertilizers probably will prove unprofitable at the present time. On these types the supply of potassium is undoubtedly adequate to meet the needs of many crops. Commercial potassium fertilizers may be used with very profitable effects on alkali spots or on peat or muck areas. In some cases they may be of value on some of the normal soils, but they should not be employed extensively until tests have been carried out on small areas and the value of the application definitely shown.

In some instances complete commercial fertilizers may be used with profit, but thus far the results which have been secured with these materials applied in comparison with superphosphate have indicated that the phosphate is more profitable.

Complete commercial fertilizers are more expensive than the phosphorus carriers; hence they must bring about much larger increases in crop yields if they are to prove as economical. The experimental results which have been secured, have generally indicated about the same beneficial effects from the fertilizers tested as by the use of superphosphate. The general application of complete fertilizers to the soils of this county cannot be recommended at this time. Farmers who are interested are urged to test a complete brand in comparison with superphosphate before making large applications of a complete fertilizer. There is no objection to the use of any complete commercial fertilizer provided it brings about profitable crop increases. It is entirely a question of economic returns.

Liming

Most of the soil types in Carroll County are acid in reaction at least in the surface soil, and, therefore, are in need of lime. The Carrington and Clarion soils on the drift upland, the Marshall silt loam on the loessial upland, the O'Neill, Bremer and Waukesha soils on the terraces and the Wabash types on the bottoms are all acid in reaction, and the acidity, while frequently not high in the surface soil, generally extends thruout the three-foot section with the exception of the soils of the Clarion type, which are very apt to show a considerable content of lime in the lower soil layers. The Webster, Pierce, Fargo and Lamoure types are well supplied with lime, at least in the subsoil, and in general show a high content of lime thruout the surface soil.

For the best growth of general farm crops and especially for such crops as alfalfa and sweet clover, any acidity in the surface soil must be corrected by the proper application of lime. The figures given in the tables earlier in this report, showing the lime requirements of the individual soil types, are merely indicative of the needs of the soils in this county. Acidity varies widely in different soils and even in soils of the same type in different areas. Before lime applications are made, therefore, the needs should be determined for each individual field. Samples should be taken from each field and tested for lime needs before any addition is made. Only in this way will it be possible to supply the proper amount of lime. It is recommended that the soils of the Carrington, Clarion, Marshall, O'Neill, Bremer, Waukesha and Wabash types be tested for acidity and that lime be applied as needed, if the most satisfactory crop yields are to be secured. In some cases also the surface soils of the Webster series are in need of lime, and in such cases additions are necessary, especially for new seedings of alfalfa or sweet clover. Farmers may test their own soils for acidity or lime requirement, but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.

The experiments which have been discussed earlier in this report have indicated the large value of applications of lime to some of the acid soils in the county. The experiences of many farmers also have indicated the returns from liming these acid types. The legume crops grown in the rotation are, of course, benefited to the largest extent, but increases in the yields of general farm crops are also frequently secured. In all cases where the soils show acidity, it is very important that lime

be applied. Further information regarding the use of lime on soils, losses by leaching and other problems connected with liming, are given in Extension Service Bulletin 105, of the Iowa Agricultural Extension Service.

Drainage

The majority of the upland soils in Carroll County are fairly well drained naturally. The rather extensive drainage system, especially in the western part of the county, is shown on the drainage map given earlier in this report. In the loessial section or western half of the county, the larger streams with their tributaries and intermittent drainageways extend into practically all parts of the upland. In the eastern part of the county, however, there are broad, level, upland areas which are naturally rather poorly drained. The lack of drainage on these broad divides is indicated on the drainage map. It is in these areas that the soils of the Webster series are mapped, the Webster loam and the Webster silty clay loam. Where these types occur on the uplands, drainage is usually very poorly developed and frequently quite inadequate. On the terraces the Bremer soils and the Fargo types are particularly in need of drainage. They are level to flat in topography, often occupying a depressed position on the second bottoms. They are also heavy in texture in the subsoil and tiling is necessary for satisfactory crop yields. On the bottomlands the Lamoure and Wabash types are all in need of drainage. In many cases, of course, they are in need of protection from overflow if they are to be made productive.

Whenever drainage is inadequate the installation of tile is very desirable. Land which is too wet will not produce satisfactory crops, and while the expense of tiling may be considerable, the increased crop yields secured will more than warrant the outlay. In the Webster soils on the uplands in Carroll County and in some other of the upland areas where the soils are not properly drained, tiling will be of value. In the Bremer and Fargo types on the terraces, the installation of tile is very necessary. In the bottomland types tiling may be of large value after the soils have been protected from overflow.

The Rotation of Crops

It is generally recognized that the continuous growing of one crop will quickly reduce the fertility of the soil. In spite of this fact, however, the large returns from the growing of certain crops often induces farmers to follow the destructive one crop system. Many experiments and the results of much practical experience has shown that it is much more profitable to follow a good rotation of crops even if crops of less money value are included. This is due to the fact that yields of a single crop are so rapidly reduced that soon the growing of the crop will become unprofitable. Farmers in Carroll County should plan to follow good rotation systems if they expect to continue to secure the best crop yields and to keep their land permanently productive.

There have been no special rotation experiments carried out in this county, but many rotations have been practiced successfully in other parts of the state, and they are generally satisfactory for average farm conditions. No one rotation can be recommended as most desirable for all conditions. Almost any rotation will

prove of value provided it contains a legume crop and a money crop. The following rotations which are in general use may serve as a basis upon which rotations suitable for Carroll County may be planned.

1. SIX-YEAR ROTATION

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover or clover and grass)
Fourth year—Clover, or clover and grass
Fifth year—Wheat (with clover or grass and clover)
Sixth year—Clover, or clover and grass

This rotation may be reduced to a five-year rotation by cutting out either the second or sixth year and to a four-year rotation by omitting the fifth and sixth years.

2. FOUR OR FIVE-YEAR ROTATION

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover or with clover and timothy)
Fourth year—Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

3. FOUR-YEAR ROTATION WITH ALFALFA

First year—Corn
Second year—Oats
Third year—Clover
Fourth year—Wheat
Fifth year—Alfalfa (The crop may remain on the land five years. This field should then be used for the four-year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-year rotation)

4. FOUR-YEAR ROTATIONS

First year—Wheat (with clover)
Second year—Corn
Third year—Oats (with clover)
Fourth year—Clover

First year—Corn
Second year—Wheat or oats (with clover)
Third year—Clover
Fourth year—Wheat (with clover)

First year—Wheat (with clover)
Second year—Clover
Third year—Corn
Fourth year—Oats (with clover)

5. THREE-YEAR ROTATIONS

First year—Corn
Second year—Oats or wheat (with clover seeded in the grain)
Third year—Clover (In grain farming, only the grain and clover seed should be sold; most of the crop residues such as corn stover should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop)

First year—Corn
Second year—Oats or wheat (with clover)
Third year—Clover

First year—Wheat (with clover)
Second year—Corn
Third year—Cowpeas or soybeans

The Prevention of Erosion

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. It occurs to some extent in Carroll County, the Carrington and Clarion soils on the drift uplands being particularly affected. The other up-

land types are also more or less influenced, particularly the Marshall silt loam in the western part of the county. Wherever serious washing of the land occurs and gullies are formed, it is very desirable that some means be taken to prevent the loss of fertility which occurs.

Various methods are followed for the control and prevention of erosion in Iowa. These methods differ somewhat depending upon the type of erosion. Erosion due to "dead furrows" may be controlled by "plowing in", by "staking in" or by the use of earth dams.

Small gullies may be filled by the "staking in" operation, by the use of straw dams, earth dams, Christopher or Dickey dams, Adams dams, stone dams, rubbish dams, woven wire dams or concrete dams. They may be prevented from occurring by thoro drainage or by the use of sod strips. Large gullies are similarly filled or prevented from occurring. Erosion in bottomlands is prevented by straightening the streams, by tiling and by planting trees in the drainage channels. Hillside erosion is controlled by the use of organic matter, by growing cover crops, by contour plowing, by terracing, by deep plowing and by the use of sod strips.*

INDIVIDUAL SOIL TYPES IN CARROLL COUNTY**

There are 20 individual soil types in Carroll County which with the steep phase of the Clarion fine sandy loam and the colluvial phase of the Wabash silt loam make a total of 22 separate soil areas. They are divided into four groups on the basis of their origin and location. These groups are drift soils, loess soils, terrace soils and swamp and bottomland soils.

Drift Soils

There are seven drift soils and these with the steep phase of the Clarion fine sandy loam make a total of eight individual drift soil areas. Together they cover 43.4 percent of the total area of the county. The various soil types are classified in the Carrington, Webster, Clarion and Pierce series.

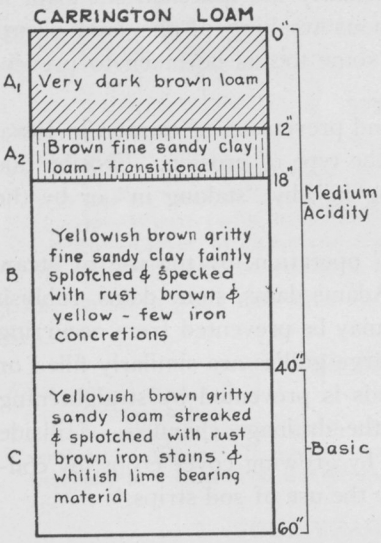
CARRINGTON LOAM (1)

The Carrington loam is the largest drift soil and the second largest individual soil. It covers 19.5 percent of the total area and occurs in all parts of the county. Thruout the areas of the Marshall silt loam in the western part it is found only along the lower portions of the more gentle stream slopes where erosion has removed the covering of loess and exposed the underlying drift. In the eastern part, however, the Carrington loam is very extensive. Thruout Kniest, Pleasant Valley, Richland and Union Townships, the areas are large and continuous, and in other parts of the county they are moderately large but isolated.

The surface soil of the Carrington loam is a dark grayish-brown loam, extending to a depth of about 12 inches. When wet this surface layer appears almost black in color. From 12 to 18 inches the subsurface soil is a very dark brown to yellowish-brown, gritty,. fine sandy clay loam. Below this point the true subsoil is a

*See Bul. 183. Soil Erosion in Iowa, Iowa Agr. Exp. Station, and Extension Service Bulletins 93, 94, 95, 96, Agricultural Extension Service, Iowa State College.

**The descriptions given in this section of the report very closely follow those in the Bureau of Soils report.



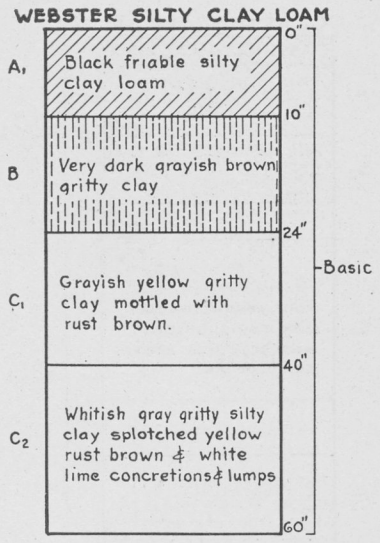
yellowish-brown, somewhat gritty, fine sandy clay slightly splotched with rusty brown and yellow. Some iron concretions occur in this layer and the content of fine gravel is considerable. The substratum between 40 and 60 inches consists of a yellowish-brown gritty, sandy loam streaked and splotched with rusty brown iron stains. The partly weathered parent material below 60 inches and to a depth of 78 is a yellowish-brown, gritty, fine sandy loam mottled, splotched and streaked with gray and rusty brown. Between 78 and 84 inches there is a pale yellowish-brown, silty material containing a considerable amount of fine and very fine sand.

There are many slight variations in the color, texture and thickness of the various layers in the Carrington loam in different areas. In the more rolling areas on ridges, hillsides and kames, the content of fine and medium sand is highest and the color is somewhat lighter, while in the undulating areas the silt content is higher than average and the soils are darker due to higher content of organic matter. In small local pockets in the vicinity of the Raccoon River, the subsoil is a sticky, fine, gravelly sand. Thruout Wheatland, Kniest, Maple River and Pleasant Valley townships, the drift plain merges gradually into the loessial uplands. The depth at which the glacial material is reached is necessarily so variable that the boundaries between the loam and the silt loam are placed rather arbitrarily. There are included with the Carrington type some narrow swales and drainageways which would have been separated as the colluvial phase of the Wabash silt loam had they been of sufficient size.

The topography of the Carrington loam is usually undulating to rolling and drainage is well established. The type is all under cultivation or in pasture. The uncultivated areas afford a luxuriant growth of grass which provides excellent grazing. The chief crops grown are corn, oats and hay. Corn yields from 35 to 43 bushels per acre, oats from 30 to 65 bushels per acre and hay from 1½ to 2½ tons per acre. Alfalfa grows very satisfactorily under proper conditions and yields from 2½ to 3 tons per acre. Minor crops grown include wheat, barley, rye, rape and soybeans. Some sweet clover is grown for forage purposes.

This soil is naturally quite productive but will respond to applications of certain fertilizing materials. The liberal application of farm manure has been found to be of large value on this soil and will bring about considerable increases in the yields of general farm crops. The soil is acid and the use of lime is necessary for the best growth of legumes. Lime will also prove of value on the other general farm crops grown. The application of a phosphate fertilizer has been shown by the experiments previously discussed and from tests carried out by individual farmers to be of value on this soil. Tests of superphosphate and rock phosphate are recommended. In some cases applications of complete commercial fertilizers

may be of value but ordinarily it is believed that superphosphate will give quite as desirable results, and the material is less expensive.



WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the second largest drift soil and the third largest type in the county, covering 9.6 percent of the total area. It occurs only in the eastern part of the county, east of a line drawn thru Breda, Carroll and Coon Rapids. It is found in large and small irregular shaped bodies within areas of the Carrington and Clarion soils. It is mapped along the headwaters of drainageways and in the broad flats and depressions on the divides of the uplands.

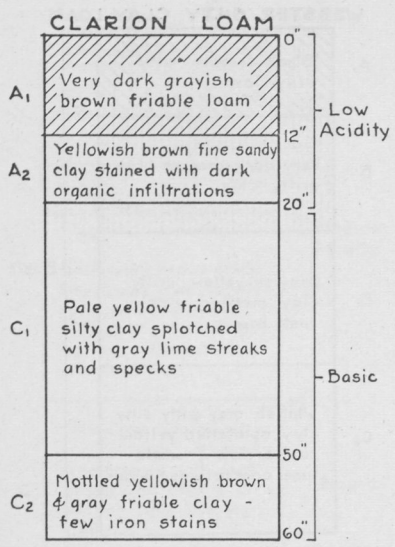
The surface soil of the Webster silty clay loam is a black, friable, silty clay loam, extending to a depth of 6 inches. The subsurface layer to a depth of 10 inches is similar to the surface soil except that it contains a higher percentage of fine sand. The upper subsoil to a depth of 14 inches is a very dark grayish-brown, gritty clay. This layer merges gradually at a depth of 24 inches into a grayish-yellow, gritty clay mottled with rusty brown. This layer usually continues to a depth of 40 inches. Thruout the lower part of the layer, there are fragments of the parent till. Lime occurs in the subsoil and frequently up thru the surface layers. Below 40 inches and continuing to a depth of 60 inches, the parent material is a whitish-gray, gritty, silty clay splotched with yellow, rusty brown and white. This material is strongly calcareous. A few variations of minor importance occur within the soil. In some places the surface soil varies in texture from a clay loam to a silty clay loam, and some small areas of loam have been included owing to their small extent. In topography the type is level to flat and the natural drainage is poor.

About 90 percent of the soil is under cultivation or in pasture. Corn, oats, clover and timothy are the chief crops grown. In favorable seasons corn yields from 35 to 65 bushels per acre. Occasionally much larger yields are reported by the better farmers. When the new varieties of oats, Iowa 103 and Iowa 105 are utilized, yields range from 35 to 50 bushels per acre. Formerly the oats crops were often damaged by lodging. The hay crop averages 2 tons per acre. Rye, buckwheat and sudan grass are grown on small areas.

The chief need of the Webster silty clay loam is drainage unless this has previously been effected. It will respond when newly drained to small applications of farm manure which stimulates the production of available plant food. The use of a phosphate fertilizer is desirable, and tests of superphosphate and rock phosphate are recommended. When the surface soil is acid it may be desirable to apply lime, especially for new seedings of legumes.

CLARION LOAM (138)

The Clarion loam is the third largest drift soil and the fourth largest type in



the county, covering 9.4 percent of the total area. It occurs in all parts of the county. Thruout the loess covered section, especially in the southwestern part of the area, narrow bands of this soil occur on some of the more gentle slopes where the underlying drift has been exposed. In the northeastern part of the county in the drift section, this soil is extensively developed. The larger more continuous areas are found in Grant, Glidden, Sheridan and Jasper townships.

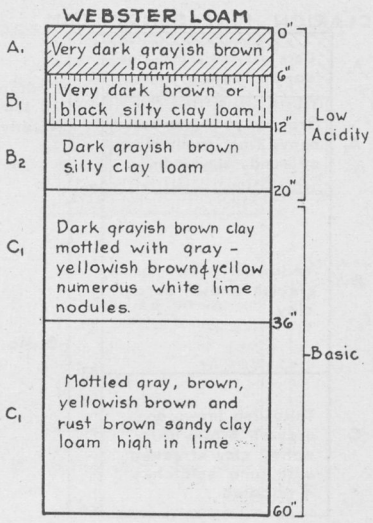
The surface soil of the Clarion loam is a very dark grayish-brown loam extending to a depth of about 12 inches. When wet the soil appears black in color. The typical subsoil is a yellowish-brown, fine, sandy clay loam faintly streaked with dark colored organic matter and containing some yellowish-brown or rusty brown discolorations in the lower part. Some gravel also occurs in the lower part of this subsoil. Below 20 inches there is usually a pale yellowish, friable, silty clay splotched with gray streaks and specks. The entire mass is strongly calcareous and some soft lime concretions occur. Scattered thru the layer there is an abundance of small nearly round gravel. Below this subsoil at a depth ranging from 50 to 70 inches, there is a mottled yellowish-brown and gray, friable, silty clay. The parent material consists of a structureless, pale yellowish-brown, light textured, silty material streaked and specked with gray and black. The entire mass is strongly calcareous.

There are some variations in the soil as mapped in the different areas. On the more rolling areas and on the slopes, the surface soils are somewhat lighter in color. In some areas where the calcareous drift material is within 22 inches of the surface, the yellowish-brown color of the upper subsoil layer has nearly disappeared. The zone of lime occurrence varies in depth to a large extent, and frequently it is difficult to separate the Clarion from the Carrington soils on this basis. Owing to their small extent, areas of Clarion fine sandy loam and sandy loam are included with the Clarion loam as mapped. In topography the type varies from undulating to gently rolling and drainage is adequate.

Practically all of the soil is under cultivation, and corn, oats and clover are the chief crops grown. Under average conditions corn will yield about 40 bushels per acre, but much larger yields are secured where the farming conditions are the best. Oats yield from 35 to 55 bushels per acre. Red clover produces 2 to 2½ tons per acre and alfalfa 3 to 3½ tons. Barley, rye, wheat and rape are minor crops and some sweet clover is grown and utilized for forage. A small acreage is devoted to sudan grass.

The Clarion loam is naturally a fertile soil and general farm crops produce satisfactory yields. Increases in yields are commonly secured, however, thru proper methods of management. Liberal applications of farm manure have been found to be of large value. The Clarion type is acid in reaction in the surface soil and

applications of lime are needed, especially for the best growth of legumes. The use of a phosphate fertilizer will undoubtedly prove of value as has been indicated by some of the tests previously referred to and from the experiences of certain farmers. Tests of superphosphate and rock phosphate are recommended.



WEBSTER LOAM (55)

The Webster loam is the fourth largest drift soil. It covers 2 percent of the total area of the county and occurs only in the northeastern half, chiefly thruout the small or depressed areas or as narrow, ribbon-like strips bordering the larger silty clay loam areas. In some places it lies between the Webster silty clay loam and the Carrington or Clarion soils.

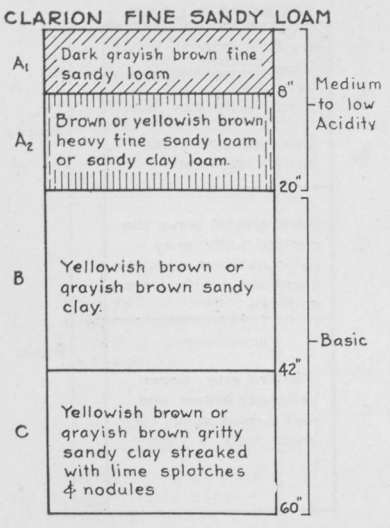
The surface soils of the Webster loam is a very dark grayish-brown loam, extending to a depth of about 6 inches. From 6 to 12 inches the soil consists of a very dark brown or black silty clay loam containing a considerable amount of fine sand. This layer is somewhat cloddy in structure and is rather compact and heavy. From 12 to 20 inches the subsurface soil is a lighter colored, dark grayish-brown and slightly heavier in texture. From this point to a depth of 36 inches it is a dark grayish-brown, slightly gritty clay splotched and streaked with gray, yellowish-brown and yellow. Below 36 inches the parent material is a mottled gray, brown, yellowish-brown and rusty brown, sandy clay loam. Medium and small sized fragments of the parent rock occur from the surface down thru the subsoil, increasing in number at the lower depths. Much of the parent material contains sufficient calcium carbonate to effervesce freely when treated with acid. Frequently the lime extends up thru the surface soil. In topography the type is level to flat and drainage is inadequate in most instances.

Practically all of the Webster loam is under cultivation to corn, oats, clover and timothy. Corn yields from 35 to 55 bushels, oats from 38 to 50 bushels and clover and timothy from 1½ to 2½ tons of hay per acre.

When the soil is well drained crop yields are satisfactory on Webster loam, but in many cases installation of tile is necessary before the most satisfactory conditions are provided for crop production. Small applications of farm manure would be of value on this soil especially when it is newly drained. It is apt to be acid in the surface soil, and when this is true applications of lime are of value. The use of a phosphate fertilizer is recommended and tests of rock phosphate and superphosphate are very desirable.

CLARION FINE SANDY LOAM (149)

The Clarion fine sandy loam is a minor type. Together with the steep phase which is limited in area, it covers 1.7 percent of the county. It occurs only in the northeastern half as low ridges along some of the stream slopes or as low knolls within areas of the Clarion loam. The more extensive areas are found in the



northeastern part of Sheridan and Jasper townships.

The surface soil of the Clarion fine sandy loam is a dark grayish-brown, fine sandy loam, extending to a depth of 8 inches. When wet the surface soil is almost black. The upper subsoil layer continuing to a depth of 20 inches is a brown or yellowish-brown, heavy, fine sandy loam or sandy clay loam. Below this point there is a yellowish-brown or grayish-brown, sandy clay containing some fine gravel. This layer, which is about 12 inches in thickness, is highly calcareous. Below a depth of 32 inches and continuing thru 4 or 5 feet there is the highly calcareous parent material. It is much the same color as the layer above but is splotched with gray and streaked with white calcareous material. The content of fine and coarse gravel is large and increases at the lower depths.

Practically all of the Clarion fine sandy loam is under cultivation and general farm crops are grown. Yields are somewhat lower than those secured on the Clarion loam. Corn yields from 35 to 40 bushels per acre, oats from 20 to 55 bushels per acre, clover and timothy hay from 1½ to 2 tons per acre and alfalfa from 2 to 3 tons per acre. Some sweet clover is grown for forage purposes.

The chief need of this soil to be made more productive is the addition of organic matter. Liberal additions of farm manure would prove of large value. The turning under of leguminous crops as green manures also would prove worthwhile. The type is acid in reaction in the surface soil and applications of lime are necessary especially for new seedings of legumes. The use of a phosphate fertilizer would undoubtedly prove of value and tests of superphosphate are recommended.

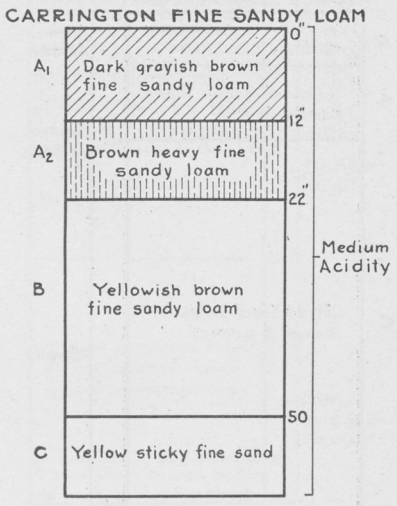
CLARION FINE SANDY LOAM (steep phase) (234)

The steep phase of the Clarion fine sandy loam is of minor importance, covering less than one percent of the total area. It occurs on the steeper, more eroded slopes along the Raccoon River and Purgatory Creek.

The surface soil which is about seven inches in thickness contains less organic matter than the typical soil and the color ranges from a dark grayish-brown to a very dark grayish-brown. The material is a loose, fine sandy loam. The subsoil is a yellowish-brown or grayish-brown, gritty, sandy clay which in most places shows a high content of lime. Fragments of the parent rock occur at the surface and increase in number at the lower depths. Small boulders are found thruout the soil. There are textural variations in the different areas of the type owing to the topographic position of the soil, but separation into various phases was not possible on account of the small extent of the areas.

The areas of this soil are too steep for cultivation and are left in their natural condition and utilized for pasture purposes. A scattered tree growth which covers

some of the hillsides consists chiefly of bur oak, red oak, walnut and maple.



CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type, covering 0.5 percent of the total area. It occurs thruout all parts of the drift section of the county. Except for the larger areas in Sections 7, 8 and 35, of Jasper Township and in Section 2, of Glidden Township, the soil occurs only on small knolls and ridges.

The surface soil of the Carrington fine sandy loam is a dark grayish-brown fine sandy loam, 12 to 14 inches in thickness. When wet the fields appear a dark grayish-brown or almost black in color. The upper subsoil is a slightly lighter brown, heavier textured, fine sandy loam. Below 22 to 24 inches the lower subsoil is a fine sandy loam, yellowish-brown in color. Below 50 to 60 inches the parent material consists of a yellowish, sticky, fine sand.

In the more rolling areas the color of the surface soil is somewhat lighter than typical. In a few small included areas the subsoil is lighter in texture approaching a loamy, fine sand. Where the Carrington fine sandy loam grades into the Carrington loam, the transition is gradual and the boundary lines are drawn arbitrarily. In topography the type is undulating to gently rolling. Drainage is inclined to be slightly excessive and crops suffer during prolonged periods of drouth.

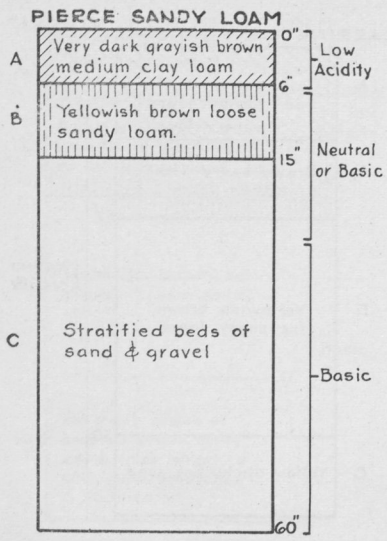
Practically all of the Carrington fine sandy loam is either under cultivation or in pasture. Corn is the chief crop grown. Oats and hay are grown for local use. Some rape is produced. The yields are lower, in general, than on the adjacent areas of Carrington loam. In wet seasons, however, the yields are quite satisfactory.

The chief need of this soil if it is to be made more productive is the incorporation of organic matter. Liberal additions of farm manure should be made, and the turning under of leguminous crops as green manures would be very desirable. The type is acid in reaction, and applications of lime are necessary for the best growth of legumes. The application of a phosphate fertilizer would be very desirable, and tests of superphosphate are urged.

PIERCE SANDY LOAM (191)

The Pierce sandy loam is a minor type, covering 0.7 percent of the total area. It occurs only in the glaciated sections of the county in kames and eskers. Some of the areas are too small to show on the map and others occupy as much as a half section of land. The most extensive area lies along the east side of Purgatory Creek in Sections 25 and 36 of Jasper Township.

The surface soil of the Pierce sandy loam to a depth of 6 inches, is a very dark grayish-brown, medium sandy loam containing some coarse material. The upper subsoil consists of a yellowish-brown, loose textured, sandy loam or loam which is underlaid at a depth ranging frem 12 to 18 inches by beds of sand or gravel. Below



24 inches the gravel is usually highly calcareous. In topography the soil is rolling to hilly and drainage is excessive.

Some of the areas of this soil are cultivated in conjunction with adjacent areas of Carrington and Clarion soils. The larger areas are usually left in pasture. Crop yields are much lower on this type than on the heavier Carrington and Clarion soils. The chief need of this type if it is to be made satisfactorily productive is the incorporation of organic matter. Liberal additions of farm manure are very desirable, and the turning under of leguminous crops as green manures is very necessary to aid in building up the supply of organic matter. The use of a phosphate fertilizer would undoubtedly be of value and tests of superphosphate are recommended.

Loess Soils

There is one loess type in the county and it is classified in the Marshall series.

MARSHALL SILT LOAM (9)

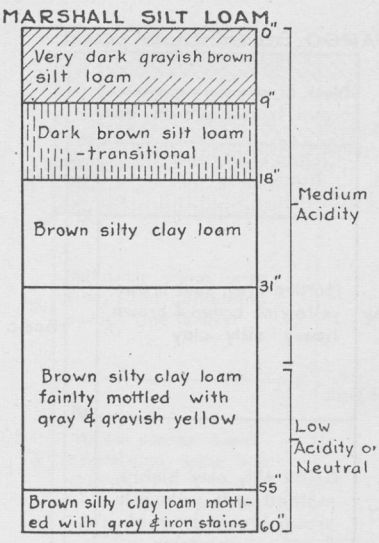
The Marshall silt loam is the only loess type and the largest individual soil. It covers 38.6 percent of the total area of the county. It occurs only in the section west of a line drawn thru Breda, Carroll, and Coon Rapids. It is found in large continuous areas broken only by the deep valleys which have been cut thru the loess often into the underlying drift.

The surface soil of the Marshall silt loam consists of a dark grayish-brown silt loam extending to a depth of about 9 inches. When wet it is almost black in color. The subsurface soil to a depth of about 18 inches is somewhat lighter in color than the surface soil and is about the same in texture. The color is not uniform but consists of many light and dark spots, owing to the movement of the dark colored organic matter from above down into the subsurface layer. This subsurface soil is somewhat more compact than the surface. The subsoil below 18 inches and extending to a depth of about 31 inches consists of a brown, silty clay loam, faintly mottled with gray and grayish-yellow in the lower part of the layer. Some iron concretions are present. The substratum to a depth of 83 inches is very similar to the true subsoil except that it is more heavily mottled with iron stains and concretions. Below this point is a grayish-yellow, plastic, silty clay loam. In general, no calcareous material occurs thruout the soil section.

The type is quite uniform in the different areas in which it occurs, altho there is some slight variation in color in different places. On the more eroded areas the surface layers are shallower, and on the more undulating areas such as those near Templeton and Breda, the dark colored surface layer ranges from 18 to 20 inches in thickness. Included within areas of the soil as mapped are very small local patches which differ from the typical in that lime concretions occur thruout the

soil section. Such areas are most conspicuous in the vicinity of Carroll but are of rather common occurrence thruout the various areas of the type.

In topography the Marshall silt loam ranges from gently undulating to rolling, the greater part of the soil having a moderately rolling surface with well rounded, evenly sloping hills. Drainage is well established. On the steeper slopes there is sufficient washing of water to bring about some damage thru erosion.



Practically all of the Marshall silt loam is under cultivation or in pasture. The only tree growth consists of windbreaks of evergreens, maple, cottonwood and elm. Corn is the chief crop grown and average yields amount to 40 bushels per acre. Much larger yields have been reported, however, by the better farmers. Oats are grown on practically all of the farms and yield from 40 to 60 bushels per acre with maximum yields ranging from 65 to 75 bushels per acre. Clover and timothy constitute the chief hay crop and yield from 1½ to 2½ tons per acre. Some alfalfa is grown and sweet clover is also utilized to some extent for forage purposes. Barley and rye are minor crops. Some soybeans are grown, chiefly with the corn that is to be used for silage.

The Marshall silt loam is naturally a productive soil and yields of general farm crops are usually quite satisfactory. It will be benefited, however, by liberal applications of farm manure and the turning under of leguminous crops as green manures. The large beneficial effects of farm manure have been evidenced in the experiments referred to earlier in this report. The type is acid in the surface soil and generally thruout the soil section, and applications of lime are very necessary, especially for the best growth of legumes. The use of a phosphate fertilizer will prove of value as is shown in the experiments discussed earlier, and tests of superphosphate and rock phosphate are recommended.

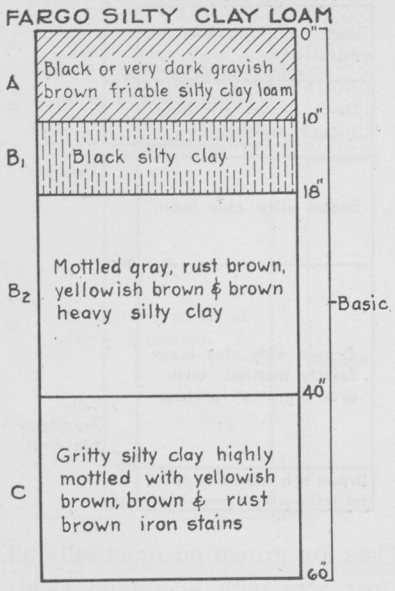
Terrace Soils

There are eight terrace soils in the county, classified in the Fargo, O'Neill, Bremer and Waukesha series. Together they cover 4.6 percent of the total area.

FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is the largest of the terrace types, covering 1.2 percent of the total area. It occurs only in the drift section of the county in the eastern part, being found in old lake beds and stream basins. There are a number of areas of the type scattered thruout the drift uplands, the more extensive areas being found in the southeastern quarter of the county near Carrollton and Coon Rapids.

The surface soil of the Fargo silty clay loam consists of a black, or very dark grayish-brown, friable, silty clay loam, extending to a depth of 10 or 12 inches. It contains a high percentage of organic matter and much calcareous material.



The subsoil to a depth of 18 or 20 inches is a black, silty clay. This is underlaid to a depth of 40 or 45 inches by a mottled gray, rusty brown, yellowish-brown and brown heavy silty clay. Both the surface soil and the subsoil are high in lime content, the greatest concentration occurring between the depths of 10 and 20 inches. The natural drainage of the soil is poor, owing to the topographic position and the heavy texture of the subsoil.

The well drained areas of the Fargo silty clay loam are used chiefly for the growing of corn. In undrained areas wild grasses grow luxuriantly and in some places are cut for hay but a greater acreage is devoted to pasture. The chief need of this soil if it is to be cultivated is the installation of an adequate drainage system. It is naturally a fertile soil and when well drained will produce high crop yields. It will be benefited by an application of a phosphate fertilizer, and tests of rock phosphate and superphosphate are recommended. Small applications of farm manure would be of value on this soil when it is newly drained, but large applications should not be made, especially not preceding the growing of a small grain crop owing to the danger of causing the crop to lodge.

O'NEILL LOAM (108)

The O'Neill loam is the second largest terrace type, covering 0.9 percent of the total area. It occurs in all parts of the county except the southwestern quarter, and is found in more or less isolated areas on the second bottoms of the various rivers and creeks. The largest area is found along Spring Branch in Pleasant Valley Township. The type occurs from 10 to 15 feet above the normal water level of the rivers and from 6 to 8 feet above that of the creeks.

The surface soil of the O'Neill loam is a dark grayish-brown or almost black mellow loam extending to a depth of 14 inches. The subsoil to a depth of 20 inches is a brown, gritty, sandy loam. This layer grades into a sticky sand which contains some clay and which in turn is underlaid at a depth of 24 inches by a yellowish-brown or yellowish, loose, fine sand containing some fine gravel. At a depth of 40 inches, the substratum consisting of a yellowish coarse sand, is encountered.

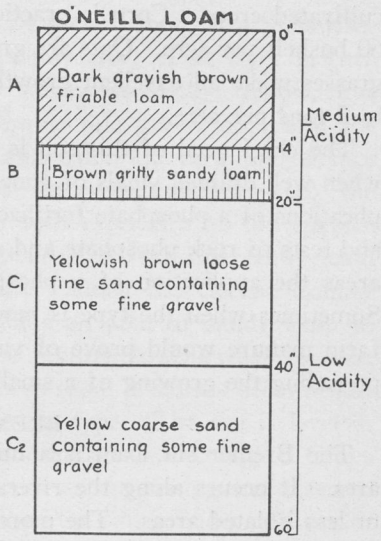
The different areas of the O'Neill loam are generally uniform in color, texture and general characteristics except in three very small areas along Willow Creek in Sections 11, 14 and 24 of Richland Township. These areas differ from the typical soil in that the sand and gravel substratum shows some effervescence with acid, indicating the presence of carbonates.

In topography the soil is level, but owing to the sandy and gravelly subsoil conditions, drainage is excessive, and in most areas the type is inclined to be drouthy.

Practically all of this soil is under cultivation. Corn is the principal crop and yields from 25 to 33 bushels per acre. Oats yield from 25 to 35 bushels per

acre. Timothy and clover constitute the chief hay crop and in normal seasons yield from 1 to 1½ tons per acre. In dry seasons the yields of general farm crops are apt to be very much reduced owing to the drouthy character of the soil.

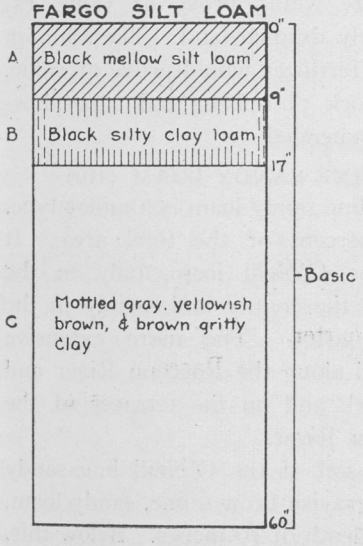
The chief need of this soil if it is to be made more productive is the liberal addition of organic matter. Large applications of farm manure would prove of value on this type and the turning under of leguminous crops as green manures would also help. This type is acid in reaction and the use of lime is necessary for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value and tests of superphosphate are recommended.



FARGO SILT LOAM (152)

The Fargo silt loam is the third largest terrace type, covering 0.8 percent of the total area. It occurs in old lake beds and on stream terraces in similar positions to those occupied by the areas of the Fargo silty clay loam. It is found thruout the drift section of the county, the more extensive areas occurring in the southeastern quarter in the vicinity of Carrollton. There are two small areas east and west of Breda in the northwestern part of the county.

The surface soil of the Fargo silt loam consists of a black, mellow silt loam containing some fine and medium sand. This is underlaid by a black, silty clay loam subsoil which is about 8 inches in thickness. Beneath this layer is a mottled gray, yellowish-brown and brown, gritty clay. All three of the layers of soil are highly calcareous, the amount of lime present increasing at the lower depth. At a depth of about 40 inches there are generally some soft lime concretions. In Section 30 of Richland Township and in Sections 5, 6 and 8 of Union Township, two areas about 80 acres in size resemble muck, but they were not separated. In these areas the soil differs from the typical Fargo silt loam in that the surface soil to a depth of 12 or 14 inches is a black, light, fluffy, smooth silt loam containing many small shells. Drainage is not well established, and in some places the surface is still covered with a growth of water-loving plants.



In topography the Fargo silt loam is level to depressed and natural drainage is poor. Tiling and ditching are necessary if these areas are to be brought under cultivation. Approximately 40 percent of the soil is now drained and in

cultivated crops. Corn is practically the only crop grown and yields from 40 to 60 bushels per acre. Oats are grown to some extent but are apt to lodge. Native grasses make an excellent growth and are usually cut for hay, yielding from 1½ to 2 tons per acre.

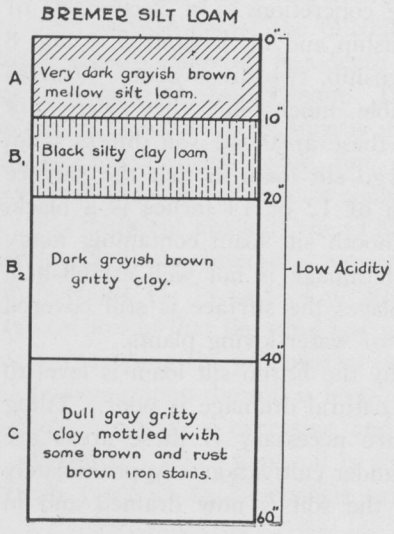
The chief need of this soil is drainage. It is naturally a productive type, and when well drained yields of general farm crops will prove quite satisfactory. Applications of a phosphate fertilizer would undoubtedly prove of value on this type, and tests of rock phosphate and superphosphate are urged. On the newly drained areas the application of a phosphate fertilizer would prove of particular value. Sometimes when the type is newly drained the application of a small amount of farm manure would prove of value, but large additions should not be made just preceding the growing of a small grain crop.

BREMER SILT LOAM (88)

The Bremer silt loam is a minor type, covering only 0.6 percent of the total area. It occurs along the rivers and larger creeks of the county in small, more or less isolated areas. The more extensive areas are found on the terraces of the Raccoon River.

The surface soil of the Bremer silt loam is a very dark grayish-brown, mellow loam from 9 to 12 inches in thickness. The subsoil is a black, silty clay loam, underlaid at a depth of 20 inches by a very dark grayish-brown or dark grayish-brown, gritty clay. Some variations occur in the mapped areas of the type, the more conspicuous being found along the west side of the Raccoon River in Sections 1 and 2 of Glidden Township.

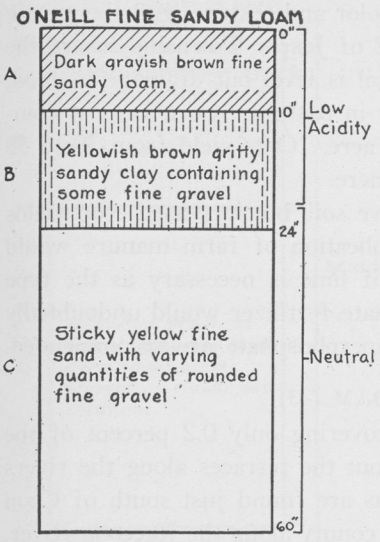
The type is flat to very gently sloping in topography, and drainage is usually adequate for crop needs. The soil is well above ordinary overflow. Practically all of it is under cultivation to corn, oats and hay or is in pasture. The yields are much the same as on the Fargo silt loam. Wherever drainage is not well established, tiling should be practiced if the soil is to be made satisfactorily productive. The soil is acid and in need of lime. The application of small amounts of farm manure would prove of value, especially on newly drained land. The addition of a phosphate fertilizer would prove of value, and tests of rock phosphate and superphosphate are recommended.



O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is a minor type, covering 0.5 percent of the total area. It occurs, like the O'Neill loam, only in the eastern half of the county and mainly in the northeastern quarter. The more extensive areas are found along the Raccoon River and Purgatory Creek and on the terraces of the Middle Raccoon River.

The surface soil of the O'Neill fine sandy loam is a dark grayish-brown, fine, sandy loam, extending to a depth of 10 inches. Below this,



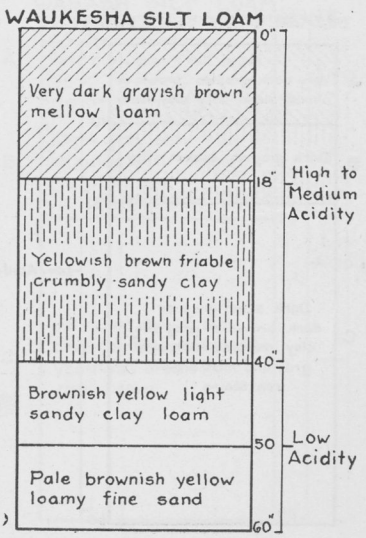
to a depth of 24 inches, there is a yellowish-brown, gritty, sandy clay. This layer in turn grades into a somewhat sticky, yellow, fine sand. Considerable fine gravel occurs in the lower subsoil and often up thru the surface layers. There are some variations in the texture of the soil, especially at the surface where it ranges from a very fine sandy loam to a sandy loam. Along the Greene County line where it joins an area of sandy loam in that county, the texture is somewhat coarser. As the area was so small it did not seem necessary to separate the type. The soil is level in topography and drainage is excessive. Crops suffer from drouth except during wet seasons.

Practically all of the soil is under cultivation or is utilized for pasture. Corn yields from 25 to 30 bushels per acre, oats from 25 to 38 bushels per acre and hay about one ton. The soil is drouthy and yields are often very low. Some alfalfa and sweet clover are grown, and in favorable seasons with good preparation of the soil, satisfactory yields are secured.

To be made more productive the type is chiefly in need of organic matter. Liberal applications of farm manure will prove of value, and the turning under of leguminous crops as green manures is very desirable. The soil is acid and in need of lime, especially for legume growth. The use of a phosphate fertilizer would prove of value and tests of superphosphate are recommended.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type, covering only 0.3 percent of the total area. It occurs on the second bottomlands along the Raccoon River, the Middle Raccoon River and Brushy Fork Creek. It is found about 3 to 5 feet above the level of the first bottoms and from 8 to 15 feet above the level of the streams.



The surface soil of the Waukesha silt loam consists of a dark grayish-brown, mellow, silt loam, extending to a depth of about 18 inches. In virgin areas the surface soil is somewhat lighter in color to a depth of about 2 inches. The true subsoil is a yellowish-brown, friable and crumbly, sandy clay faintly streaked with dark colored material. Below 40 inches and continuing to a depth of 50 inches, is a brownish-yellow, light, sandy clay loam, containing iron concretions and rusty brown stains which increase in number at the lower depths. Below 50 inches is a pale brownish-yellow, loamy, fine

sand. The areas of the soil are uniform in both color and texture with the exception of a few small patches in Sections 17 and 18 of Jasper Township where the texture approaches a loam. In topography the soil is level but drainage is good.

Practically all of the soil is under cultivation or in pasture. Corn is most commonly grown, yielding from 35 to 45 bushels per acre. Oats yield from 30 to 55 bushels per acre and hay from 1½ to 2 tons per acre.

The Waukesha silt loam is naturally a productive soil, but increased crop yields may be secured thru proper treatment. The application of farm manure would be of considerable value on this soil. The use of lime is necessary as the type is acid in reaction, and the application of a phosphate fertilizer would undoubtedly prove of value. Tests of rock phosphate and superphosphate are recommended.

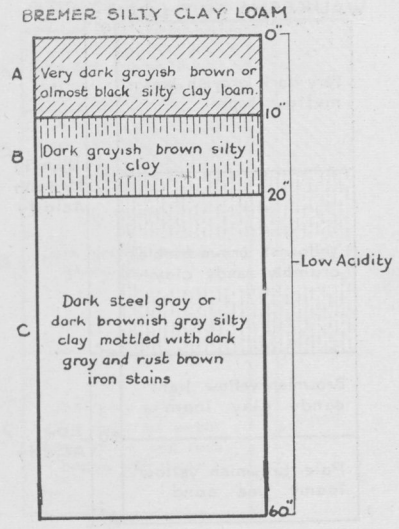
BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor type, covering only 0.2 percent of the total area. It occurs in small isolated areas thruout the terraces along the rivers and larger creeks of the county. The larger areas are found just south of Coon Rapids and in the extreme northeast corner of the county along the Raccoon River.

The surface soil of the Bremer silty clay loam is a very dark grayish-brown or almost black, friable, silty clay loam, 10 or 12 inches in thickness. This is underlaid by a dark grayish-brown or dark brownish-gray, silty clay from 8 to 15 inches thick, which is underlaid in turn by a dark steel gray or dark brownish-gray, silty clay, mottled with dark gray and rusty brown.

In topography the Bremer silty clay loam is flat or very gently sloping. The soil lies 10 to 15 feet above the normal stream level. Drainage is generally inadequate and crops often suffer from an excess of water during prolonged periods of high rainfall.

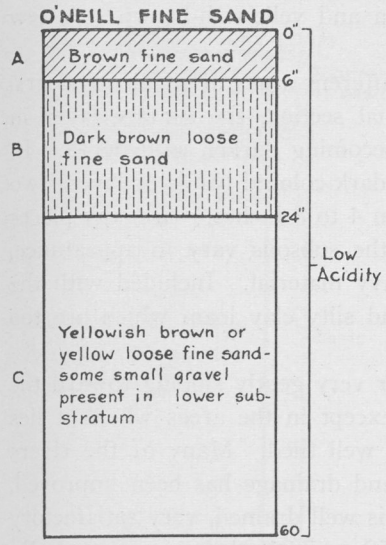
Practically all of the type is under cultivation and used for the production of corn. Yields of 40 to 50 bushels are common. Bluegrass and native grasses make a luxuriant growth and are utilized for pasture and hay purposes especially on the undrained areas.



The chief need of this soil is adequate drainage. Small applications of farm manure would prove of value on newly drained areas, but large additions should not be made and certainly not preceding the growing of small grain crops owing to the danger of causing the crops to lodge. Applications of lime are necessary as the type is acid in reaction. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of rock phosphate and superphosphate are recommended.

O'NEILL FINE SAND (146)

The O'Neill fine sand is a minor type, covering 0.1 percent of the total area. It occurs in association with the O'Neill loam, usually occupying small knolls and long low ridges. It



occurs chiefly in the northeastern quarter of the county along the Raccoon River.

The surface soil of the O'Neill fine sand is a brown or medium dark brown fine sand or loamy fine sand, extending to a depth of 6 to 8 inches. Below this point is a dark brown, fine sand, extending to a depth of 22 to 24 inches. The subsoil is a yellowish-brown or yellowish, loose textured, fine sand which extends to a depth of 42 or more inches without change. The type is rather uniform in the areas in which it occurs. In topography it is undulating or gently rolling. Drainage is excessive, owing to the sandy character of the soil and subsoil.

Very little of this type is under cultivation because of its low fertility and its tendency to drouthiness. It is left in its virgin condition and utilized for pasture. The only tree growth consists of a few willows along old fence rows. Native grasses make a rather poor growth.

The chief need of this soil if it is to be cultivated is additions of organic matter. The liberal addition of farm manure is desirable, and the turning under of leguminous crops as green manures would prove of large value. The soil is acid and in need of lime. The use of a phosphate fertilizer would undoubtedly prove of value and tests of superphosphate are recommended.

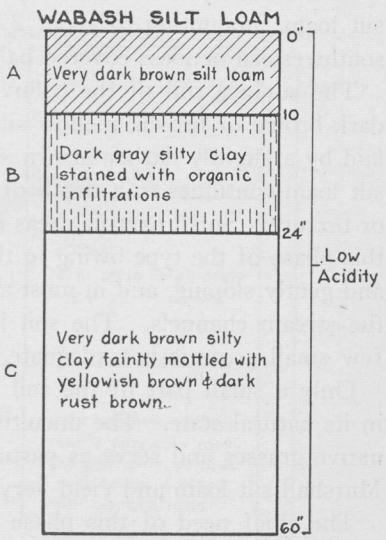
Swamp and Bottomland Soils

There are four swamp and bottomland soils which, with the colluvial phase of the Wabash silt loam, make five bottomland soil areas. Together they cover 13.4 percent of the total area, and are classified in the Wabash and Lamoure series.

WABASH SILT LOAM (26)

The Wabash silt loam together with the colluvial phase which is much less extensive in area is the fifth largest soil type in the county, covering 9.4 percent of the total area. It occurs along all the rivers and creeks. The more extensive areas are found along the Middle Raccoon and West Nishnabotna rivers, Spring Branch and Brushy Fork creeks.

The surface soil of the Wabash silt loam is a very dark grayish-brown, even textured, silt loam 10 or 12 inches in thickness. The subsoil to a depth of 24 inches is a dark gray, silty clay loam, faintly splotched with darker colors. Below this layer is a very dark brown or black



silty clay, slightly marked with dark rusty brown and yellowish-brown. A few iron stains occur.

There are many variations in this soil in the different areas in which it occurs. In the southwestern half of the county or loessial section, the surface layer in most areas is slightly lighter colored, the color becoming darker with depth. In some areas there are alternating light colored and dark colored bands or layers two or three inches in thickness, varying in depth from 4 to 8 inches. In many places along the Raccoon and Middle Raccoon rivers, the subsoils vary in appearance, showing layers of dark gray sand and black heavy material. Included with the Wabash silt loam are some areas of the loam and silty clay loam which are too small to separate on the map.

The surface of the Wabash silt loam is level or very gently sloping toward the streams. The land is generally poorly drained except in the areas where it lies 8 to 10 feet above the normal water level and is well tiled. Many of the rivers and creeks have been dredged and straightened and drainage has been improved.

Where the soil is protected from overflow and is well drained, very satisfactory crop yields may be secured. Corn yields from 50 to 70 bushels per acre under such conditions. Oats are not grown extensively owing to the danger of lodging. The use of the Iowar, Iowa 105 and Iowa 103 varieties, however, have permitted satisfactory oat growing on this soil. The greater part of the soil is left in its natural condition and is used for pasture purposes. A small acreage is utilized for hay.

The chief need of the Wabash silt loam if it is to be cultivated is adequate drainage and protection from overflow. It will be benefited by small applications of farm manure when it is newly drained. Large applications should not be made and certainly not preceding the growing of a small grain crop. The type is acid and in need of lime. The addition of a phosphate fertilizer would be of value, and tests of rock phosphate and superphosphate are recommended.

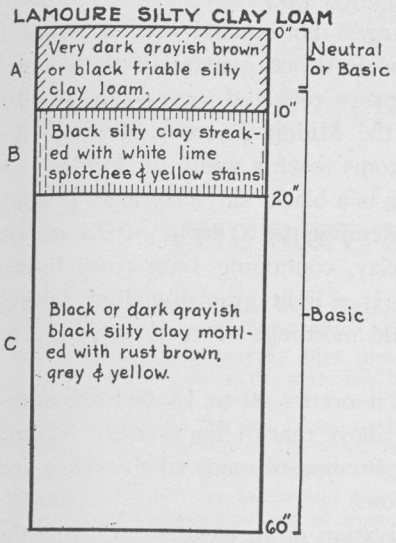
WABASH SILT LOAM (colluvial phase) (26a)

In the county there is a very small area of the colluvial phase of the Wabash silt loam, amounting to about 2 percent of the total area. It occurs only in the southwestern or loess covered half, lying along smaller intermittent drainage ways.

The surface soil of the colluvial phase of the Wabash silt loam consists of a dark brown or brown, mellow silt loam, from 12 to 18 inches in thickness, underlaid by a slightly darker brown silt loam. In some areas the dark brown, mellow silt loam continues to a depth of 3 or more feet without changing either in color or texture. Small narrow areas of the typical Wabash silt loam are included with this phase of the type owing to their small extent. The surface of the type is flat and gently sloping, and in most areas the soil lies 2 to 4 feet above the bottoms of the stream channels. The soil is subject to overflow, and drainage except in a few small areas is not adequate.

Only a small part of the soil is under cultivation, about 90 percent remaining in its natural state. The uncultivated areas support a rank growth of weeds and native grasses and serve as pasture. A few cultivated areas are farmed with the Marshall silt loam and yield very similarly when they are well drained.

The chief need of this phase of the typical soil is for adequate drainage. It



will then respond to small applications of farm manure, the use of lime to correct acidity and the application of a phosphate fertilizer.

LAMOURE SILTY CLAY LOAM (111)

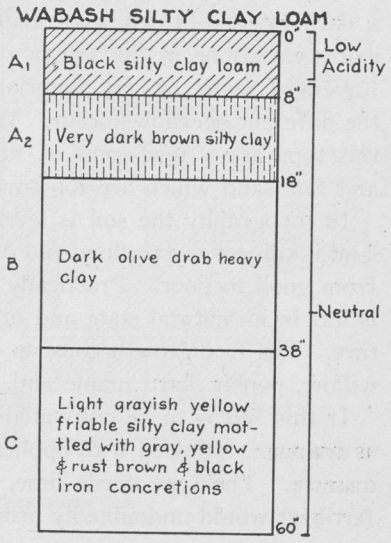
The Lamoure silty clay loam is the second largest bottomland soil, covering 2.4 percent of the total area. It occurs in a number of areas along the larger streams, being most extensively developed along the Middle Raccoon River, Storm Creek and Willow Creek. In the bottomlands just north and south of the confluence of Middle Raccoon River and Storm Creek, areas reach a width of 2 or 3 miles.

The surface soil of the Lamoure silty clay loam to a depth of 10 inches is a very dark grayish-brown or black, mellow, silty clay loam, containing a large amount of organic matter. The subsoil to a depth of 20 inches is a black silty clay, mottled and streaked with carbonaceous material and yellow stains. Beneath this and continuing to varying depths is a third layer consisting of a black or dark grayish-black, silty clay, mottled with rusty brown, gray and yellow. The two upper layers are highly calcareous, and the lime content seems to decrease in the lower part of the subsoil. The soil is uniform thruout its occurrence, except for variations consisting of small silt loam areas which are included because of their small extent.

In topography the soil is level and occurs from 8 to 10 feet above the normal level of the river and from 2 to 3 feet above that of the creek. The land is subject to overflow. Thruout the bottoms of the Middle Raccoon River and Storm Creek where sufficient tile has been laid, drainage is adequate for crop needs during normal years. In other areas, especially along Willow Creek where drainage is poor, the type presents a swampy appearance and is covered with a dense growth of water-loving plants.

About 85 percent of the soil has been reclaimed and placed under cultivation. The more extensive, higher areas are used exclusively for the production of corn which yields 45 to 60 bushels per acre. Poorly drained areas are used for pasture.

The chief need of this soil is adequate drainage if it is to be made satisfactorily productive. It should then be protected from overflow. The use of a phosphate fertilizer would undoubtedly be of value for cultivated crops, and tests of rock phosphate and superphosphate are recommended.



WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the third largest bottomland soil, covering 1 percent of the total area. It occurs only in the northeast quarter of the county, on the bottoms of the Middle Raccoon River, Storm Creek and some of the smaller drainageways. The largest areas occur along the Middle Raccoon River in the southern half of Grant Township where the bottoms reach a width of 2 miles.

The surface soil of the Wabash silty clay loam is a black, silty clay loam grading into a dark brown, heavy, silty clay layer, extending to a depth of 18 inches. Below that point is a dark olive drab, heavy clay, containing faint rusty brown mottlings and iron stains. At 38 inches there is a light grayish-yellow, friable, silty clay, with some small black concretions and mottlings of rusty brown, gray and yellow.

In topography the soil is practically flat and it occurs 10 to 15 feet above the normal level of the rivers and from 5 to 8 feet above that of the creeks. Natural drainage is insufficient. The dredging and straightening of many of the rivers and creek channels have improved drainage conditions.

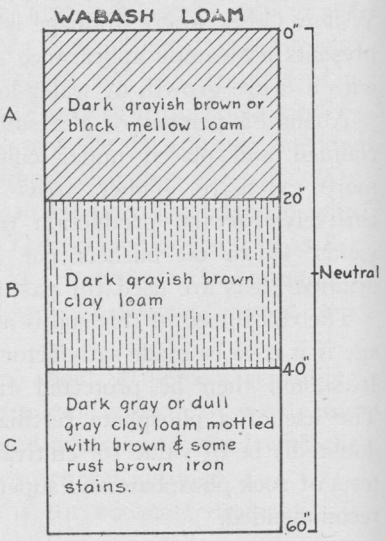
Possibly 85 percent of the soil is under cultivation or in pasture. Corn is the chief crop grown and yields from 40 to 45 bushels per acre. Oats yield from 33 to 35 bushels per acre and hay from 1½ to 2½ tons per acre. The uncultivated areas are utilized for pasture. Native grasses and bluegrass thrive.

The chief need of this soil if it is to be made more productive is adequate drainage. When this is accomplished, small applications of farm manure would be of value. Large applications should not be made preceding a small grain crop. The type needs lime. A phosphate fertilizer would undoubtedly be of value.

WABASH LOAM (49)

The Wabash loam is a minor type, covering 0.6 percent of the total area. It occurs only in the northeastern quarter in narrow strips of bottomland along the Raccoon River and Purgatory Creek.

The surface soil of the Wabash loam is a dark grayish-brown or black, mellow loam. The subsoil to a depth of 40 inches is a dark grayish-brown, clay loam. There are many variations in the soil in different areas. Layers of sandy or clay material laid down by the different overflows occur. Within areas of this type are a few areas of fine sandy loam and fine sand which are too small to separate.



In topography the soil is level to flat. The land is subject to overflow, and drainage ranges from good to poor. Practically all of the soil is left in its natural state and utilized for pasture. The tree growth consists chiefly of elm, willow, poplar, hard maple and walnut.

If this soil is to be cultivated its chief need is drainage, followed with applications of farm manure. The type needs lime. A phosphate fertilizer would undoubtedly prove of value.

APPENDIX

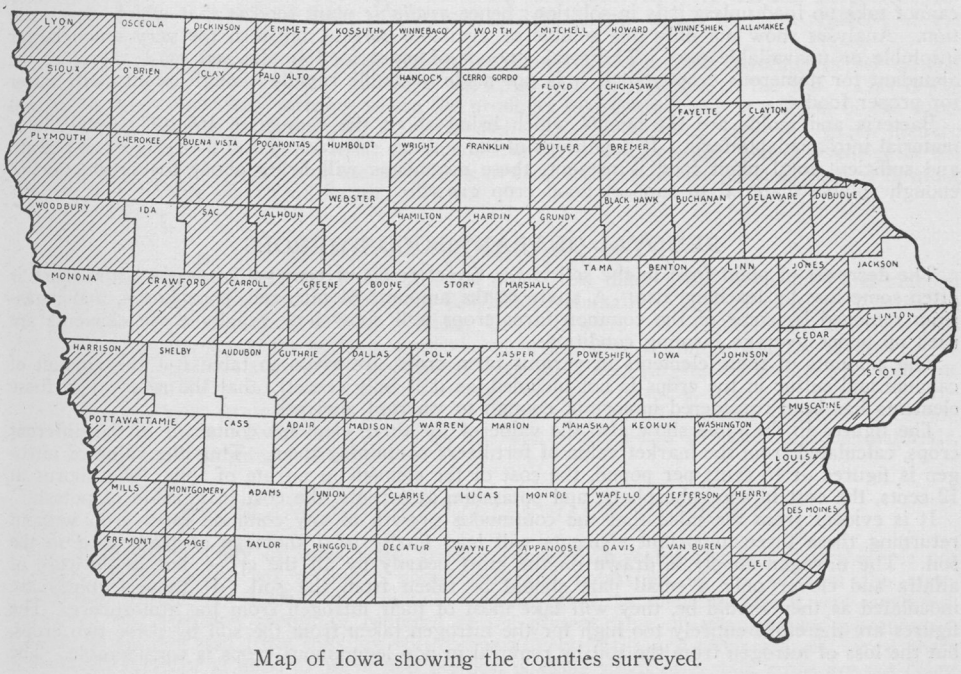
THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various



Map of Iowa showing the counties surveyed.

counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in superphosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNo_3$)), Phosphorus (P) at 12c (Superphosphate), and Potassium (K) at 6c (Potassium Chloride (KCl)).

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	-------	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	-------	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	-------	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	-------	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	-------	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food losses.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being

obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops, and the maintenance of permanent fertility and the adoption of such systems should not be delayed until the crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for crop production, largely because they help control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for lack of water necessary to bring them their food and also for lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air; all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage, and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

There are a number of explanations of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In proper rotations the time between two different crops of the same plant is long enough to allow the "toxic" substances to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reasons for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which

produce carbon dioxide and various acids which dissolve and make available tne insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of the soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is not possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, superphosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and superphosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and superphosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological force which brought about the formation of the various soil areas.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet of earth debris left after the ice of such glaciers melts, is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift

areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

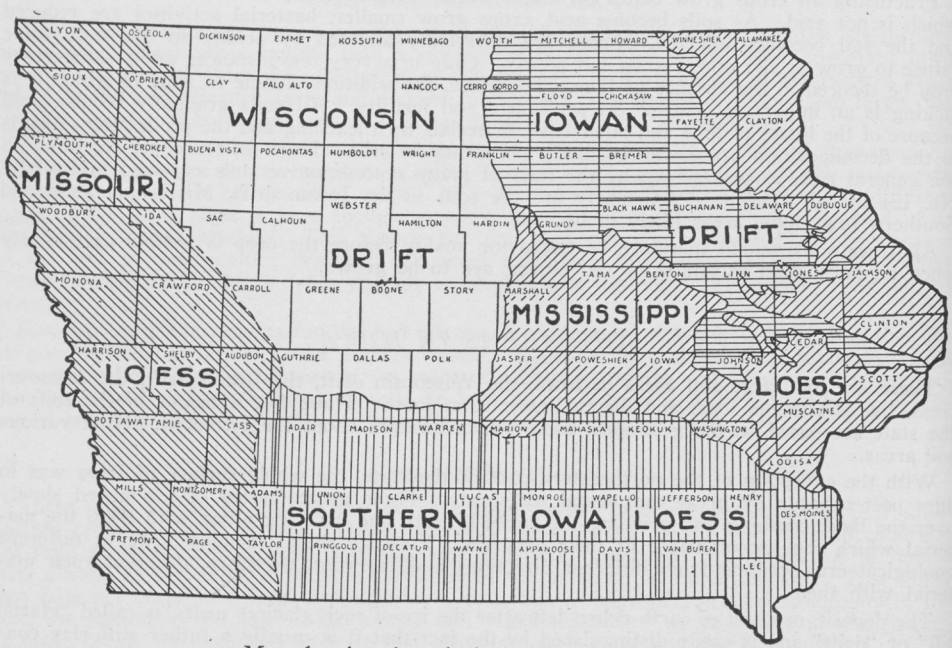
The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of the fine texture, and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further division may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large



Map showing the principal soil areas in Iowa.

areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter { All partially destroyed or decomposed vegetable and animal material.

Inorganic matter {
- Stones—over 32 mm.*
- Gravel—32—2.0 mm.
- Very coarse sand—2.0—1.0 mm.
- Coarse sand—1.0—0.5 mm.
- Medium sand—0.5—0.25 mm.
- Fine sand—0.25—0.10 mm.
- Very fine sand—0.10—0.05 mm.
- Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

* 25mm. equals 1 in. † Bureau of Soils Handbook

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over 1 inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact map of the county.